AQUARIUS/SAC-D

MISSION PLAN

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COMISION NACIONAL DE ACTIVIDADES ESPACIALES ARGENTINA

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Change Log

All changes and revisions to the SAC-D Mission Plan will be approved by the signatories identified on Page 2.

REVISION RECORD

Rev.	Date	Reason for Revision	Program Released

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1.1 Purpose

This Mission Plan defines a baseline strategy for successfully achieving the objectives of the Aquarius/SAC-D mission, within the capabilities and constraints of the mission systems, and subject to the project policies on the use of these systems. Therefore, the Mission Plan integrates the driving mission requirements and objectives, including a basic description of the mission components and how they are used to achieve those requirements. The Mission Plan also documents some design features, constraints and mission options.

This baseline plan is a reference for the development of detailed activity plans both before launch and during the mission.

1.2 Scope

The Aquarius/SAC-D Mission Plan responds to high-level project policy and requirements documents, and does not levy new mission and system requirements. It describes a baseline plan for conducting the mission, from launch to decommissioning, consistent with the requirements, capabilities and constraints that are defined in other documentation.

The baseline mission is the planned series of mission events that would normally proceed from launch to the end of the mission.

1.3 Applicable and Referenced Documents

The mission plan is directly responsive to the following documents:

- L1 SD Mission Requirements SD-121-0063
- L1 AQ Mission Requirements AQ-121-0021
- L2B AS Mission System Requirements AS-223-0101

The Mission Plan is consistent with the following documents:

- L2A SD Science Requirements SD-222-0064
- L2A AQ Science Requirements AQ-222-0039
- AS - Project Implementation Plan AS-211-0016
- L3 AS Launch Vehicle Requirements AS-323-0103
- AS - Mission Concept and Operational Scenarios AS-213-0092

2.0 Mission Overview

2.1 Mission Objectives

The Aquarius/SAC-D Mission, a cooperative mission between the Comisión Nacional de Actividades Espaciales (CONAE) and the National Aeronautic and Space Administration (NASA), has the primary objective of implementing the Aquarius and SAC-D projects as specified in the NASA-CONAE Memorandum Of Understanding (MOU), dated March 2, 2004.

For this joint mission, Argentina is providing the SAC-D spacecraft, additional science instruments and the Mission Operations Center (MOC), while NASA provides Aquarius, the salinity measuring instrument, the Aquarius Ground System and the Launch Vehicle (LV).

The SAC-D portion of the mission is managed by CONAE whereas NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California, manages the Aquarius development for NASA. NASA's Goddard Spaceflight Center (GSFC) in Greenbelt, Maryland, will build the radiometer portion of the Aquarius instrument and will process and generate the Aquarius science data products after launch.

The Aquarius Project is a three-year NASA mission selected by the Earth Systems Sciences Program (ESSP). The Aquarius Project will make pioneering space-based measurements of sea surface salinity (SSS) with the precision, resolution, and coverage needed to characterize salinity variations as specified in the Aquarius Level 1 Requirements and Mission Success Criteria. During the three-year mission, Aquarius will fly in a 657-km, 98 deg Sun-synchronous polar orbit with a 06:00 PM ascending node that provides global coverage of the ice-free ocean surfaces within a 7-day repeat cycle

The SAC-D Project is a 5 year CONAE mission that consists of the following instruments:

- Microwave Radiometer (MWR)
- New Infra-Red Sensor Technology (NIRST)
- High Sensitivity Camera (HSC)
- Data Collection System (DCS)
- Radio Occultation Sounder for Atmosphere (ROSA)
- Cosmic radiation effects and orbital debris and micrometeoroids detector (CARMEN)
- Technological Demonstration Package (TDP)

The SAC-D instruments have the following multiple objectives:

- Measurement of rain rates, surface wind speeds, water vapor and cloud liquid water, over the ocean, which will enhance the results of the Aquarius measurements.
- Measurement of the physical parameters of the High Temperature Events (HTE) on the ground, caused by biomass fires and volcanic eruptions.

- Measurement of Sea Surface Temperature (SST).
- Measurement of the temperature and humidity profile of the troposphere and the stratosphere.
- Measurement of sea ice concentration.
- Measurement of lighting, light intensity over urban areas and polar auroras.
- Receive and store meteorological and environmental data generated by the ground based measurement systems for later transmission to Cordoba Ground Station and distribution to the user community.
- Validate a newly developed GPS receiver for position, velocity, and time determination and an Inertial Reference Unit (IRU) to measure inertial angular velocity.
- To detect micrometeoroids and orbital debris to understand kinetics of space damage and evaluate orbit debris population and its evolution.

The Mission System consists of the following elements, integrated to perform the Aquarius and SAC-D mission objectives and requirements: Aquarius Instrument, SAC-D Instruments, Service Platform (S/P), Aquarius Ground System, SAC-D Ground System, and Launch Vehicle (L/V). The entire Flight System placed in orbit by the L/V, consisting of the S/P, the Aquarius instrument and SAC-D instrument suite is called the Observatory.

2.2 Mission Success Criteria

The Aquarius Mission will be considered fully successful if it:

- Makes global space-based measurements of sea surface salinity with the precision, resolution and coverage needed to investigate the coupling between ocean circulation and the global water cycle.
- Collects data sufficient to produce monthly mean estimates of sea surface salinity over three years
- Records, calibrates, validates, publishes and archives science data records and calibrated geophysical data products in a NASA Distributed Archive Center (DAAC) for use by the scientific community within the timeframe specified in the Aquarius Level 1 requirements.

The SAC-D Mission will be considered fully successful if it:

- Provides a S/P capable of accommodating the Aquarius and SAC-D instruments and conducting flight operations after a successful launch.
- Provides regular operation of the satellite and all eight instruments. The capabilities of each instrument shall meet their respective performance requirements.
- Performs weekly assessment of fires and electric storm occurrences over the Argentine territory, during the mission lifetime.
- Performs space-based measurements of wind velocity on the South Atlantic Ocean and sea ice covertures over Antarctica, for their quantification over one annual cycle.
- Acquires environmental parameters over the Argentine territory and distributes them to the users on a daily basis.

- Validates technologies for attitude and navigation control for use in future CONAE missions.
- Archives, processes and distributes the data to the scientific community.

2.3 Science Objectives

The primary science objectives of the Aquarius/SAC-D mission are to contribute to the understanding of the total Earth system and the effects of natural and human-induced changes on the global environment.

The Aquarius mission will contribute to a better understanding of ocean circulation and the prediction of changes in this circulation and its impact on Earth's climate and water cycle.

The SAC-D mission will address the Space Information Cycle II "Information System devoted to Oceanography, the Coastal Environment, Climate and Hydrology" and Space Information Cycle III "Emergency Management established in the National Space Program, Argentina in space 2004-2015". The scopes of this project are:

- Monitor environmental changes, natural hazards and sea ice.
- Monitor atmospheric parameters
- Study the effect of cosmic radiation on electronic devices
- Characterize space debris

2.4 Orbit Design

The following Science Requirements provided drivers for Orbit Design:

- Global Coverage: the entire extent (100%) of the ice-free ocean surface to at least ± 79° latitude and 300 km away from land and ice boundaries should be observed
- Swath shall be at least 300 km with gaps between the footprints within a swath not exceeding 50 km on average
- Temporal Coverage: In order to provide monthly accurate salinity measurements, each 100x100 km grid point should be visited at least 8 times per month (counting both ascending and descending passes)
- Radiometer Geometry: Zenith angle of the Sun on the footprint should be greater than 90° (in shadow) to the extent possible
- Instruments should operate in the 600 +100/- 50 km altitude range
- Orbit shall have a repeat pattern of less than or equal to 9 days maintained within ± 20 km

The selected orbit for the Aquarius/SAC-D mission is a frozen, Sun-synchronous, 657 Km altitude orbit with an Ascending Node Mean Local Time (MLT) of 06:00 PM.

Parameter	Nominal value	Remarks

Equatorial Altitude	657 Km	7-Day, 103-Revolutions Repeat Orbit
Mean Eccentricity	0.0012	Frozen
Inclination	98.01º	Sun-synchronous
Ascending Node	06:00 PM	Dawn-Dusk orbit
Perigee	90º	Frozen

Table 2-1 Orbit parameters

This orbit has the following `properties:

- It is a 7-Days, 103-Revolutions repeat orbit
- It provides global coverage over 7 days (4 repeats for both ascending and descending passes in less than 30 days)
- 06:00 PM ascending node was chosen to maximize footprint in shadow and have more coverage over the Arctic than Antarctica
- Frozen Orbit (near constant altitude for a given latitude)

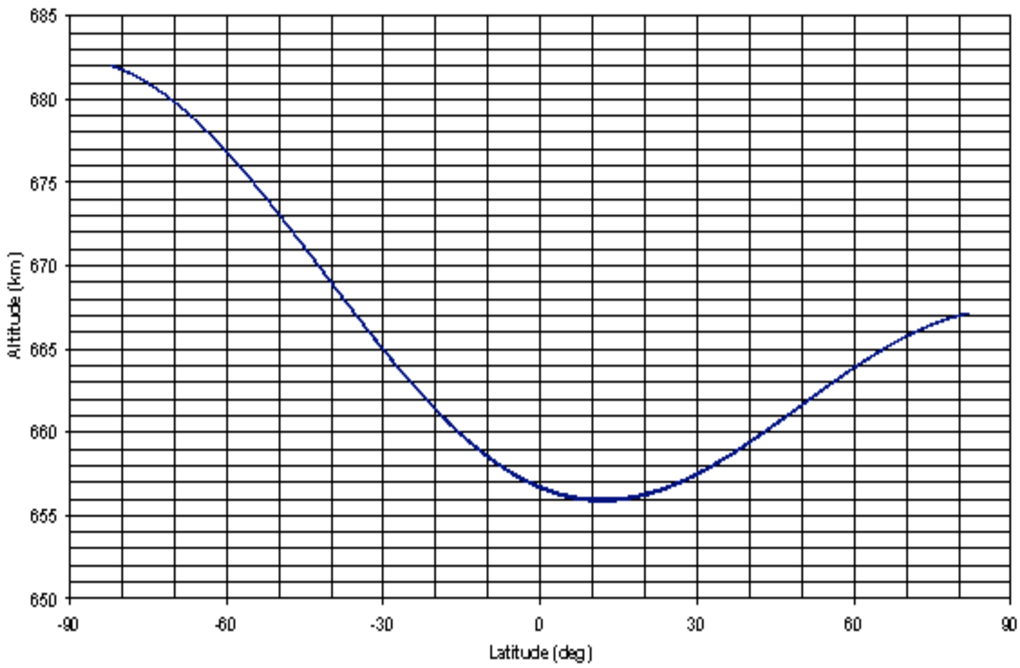


Figure 2-1 Spacecraft altitude

Because of the changing position of the Sun with respect to the orbital plane there are short periods of eclipses (approximately 3 months every year). For Aquarius/SAC-D orbit the eclipse season will take place between May and August and at southern latitudes.

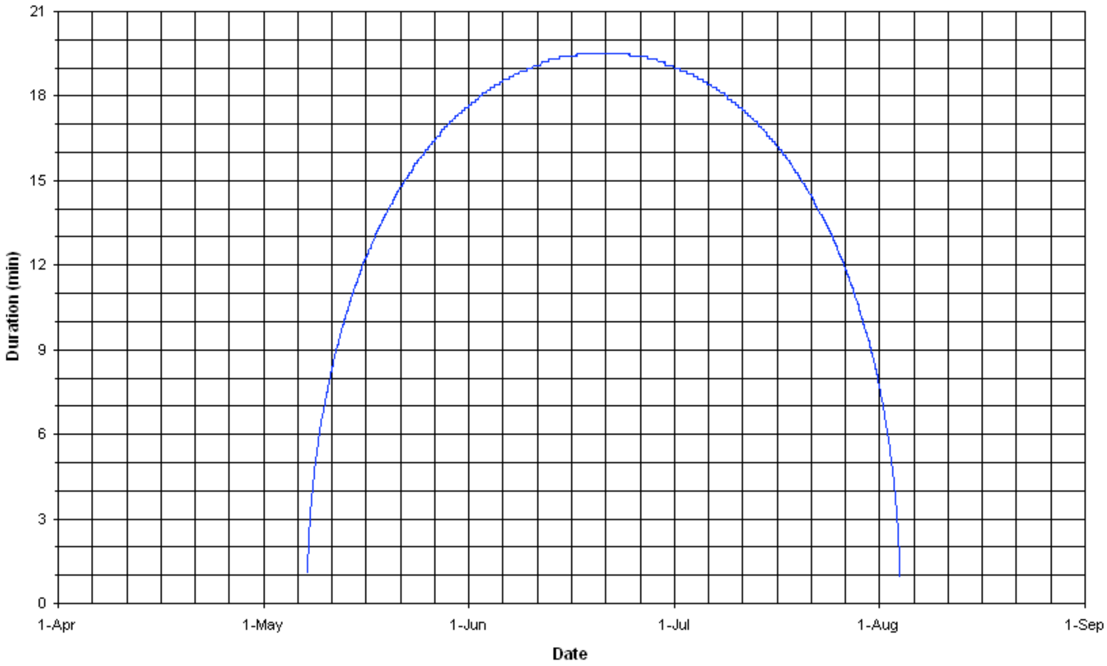


Figure 2-2 Eclipse duration

The Beta angle, defined as the acute angle between the Earth to sun vector and the instantaneous angular momentum vector of the Aquarius/SAC-D orbit, is shown in Figure 2-3 and its yearly evolution in Figure 2-4

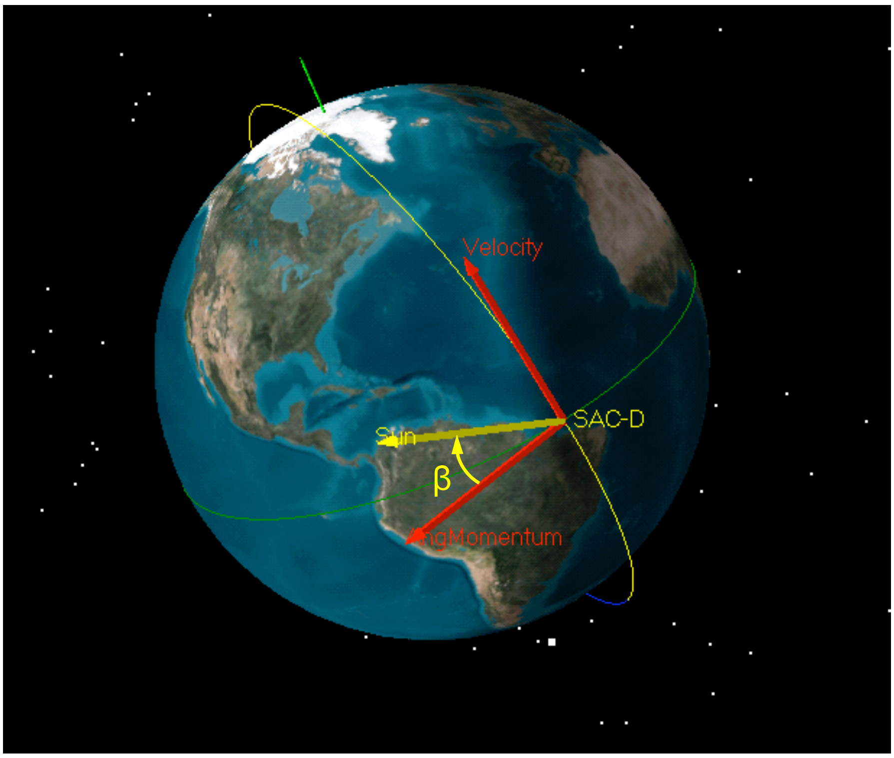


Figure 2-3 Beta angle definition

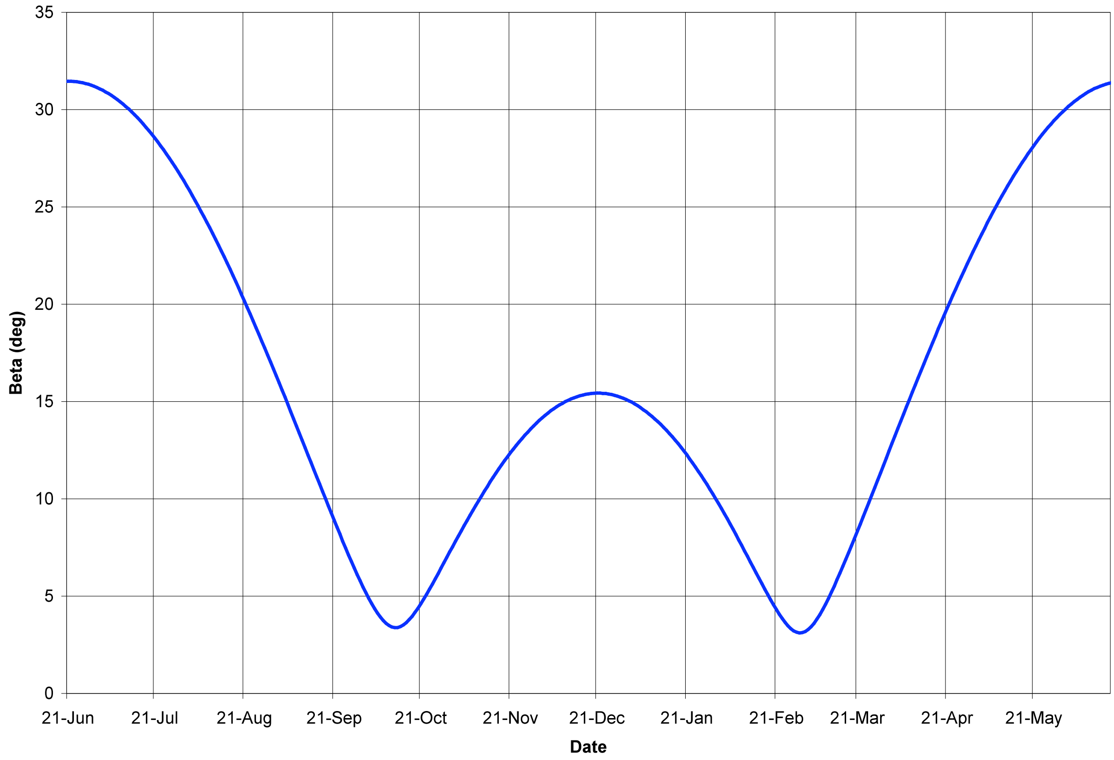


Figure 2-4 Beta angle evolution

2.5 Mission Phases

The mission is divided into several distinct phases. Each phase is characterized by a series of activities. The mission phases include the launch, turn-on and check out of the S/P and the science instruments, the routine mission operations and science data collection, the S/P and instrument decommissioning phase and the de-orbit phase.

Phase	Definition	Phase Start	Duration
Launch	The Launch Phase includes: Lift-off, ascent, fairing separation, automatic S/P turn-on sequences and separation from the L/V.	June 09, 2011	60 minutes
Early Orbit and Observatory Commissioning Phase	The Early Orbit and Observatory Commissioning Phase includes: initial ground acquisition, solar array deployment, Sun acquisition, checkout of S/P subsystems and health checks of science instruments,	June-July, 2011	Up to 45 days

	deployment of instrument antennas, orbit circularization and inclination maneuvers, and payload commissioning.		
Science Operations	The Science Operations Phase starts following Early Orbit and Observatory Commissioning Phase and lasts for the remainder of the Aquarius and SAC-D instruments functional life and within available mission resources. This phase is characterized by the collection of science data and by the transfer of science and engineering data to the ground.	July, 2011	5 years (SAC-D prime mission) 3 years (Aquarius prime mission)
Observatory Decommissioning	The Decommissioning Phase concludes the Aquarius/SAC-D science operations and powers off instruments. The orbit is lowered using the remaining hydrazine depletion to insure that reentrance will take place in less than 25 years. During this time, the spacecraft is placed in a spin mode and commanded to take the anti-sun direction causing battery discharge.	Not earlier than July, 2016	45 days

Table 2-2 Mission phases

A high-level overview timeline for the Aquarius/SAC-D mission and phases is shown in Figure 2-5.

The Launch Phase includes: lift-off, ascent, fairing separation, barbeque (BBQ) thermal maneuver, orbit injection and Observatory separation from the L/V. From liftoff until fairing separation, the Observatory will remain in the OFF state. The fairing separation event shall serve to power ON the S/P by triggering an autonomous power-ON sequence.

Following separation, the solar array will be deployed. During the Early Orbit and Observatory Commissioning Phase normal operation of the S/P basic functions and performances of each subsystem are verified. Orbital maneuvers will be performed in order to correct L/V injection errors and to achieve the nominal mission operations orbit. Next, the instrument payloads are sequentially turned-ON, checked out and calibrated.

During Science Operations, the Observatory will orbit the Earth 14-15 times per day with a period of approximately 98 minutes. The Aquarius and MWR instruments will operate for a minimum of three years; NIRST, HSC, DCS, CARMEN and TDP will operate for a minimum of five years and ROSA for a minimum of four years starting after the completion of the commissioning period. During this phase, Cold Sky Calibration maneuvers and orbit maintenance maneuvers will be performed periodically to meet requirements.

For Aquarius, the baseline mission will end following three years of operations. At which time, the Aquarius project will conduct a review to decommission the instrument (i.e., place the instrument in survival mode). Upon completion of science operations, the satellite will enter the Observatory Decommissioning Phase, when a de-orbit series of maneuvers will be performed, non-essential subsystems will be powered off, and the satellite will continue in a multi-year coast to an uncontrolled re-entry.

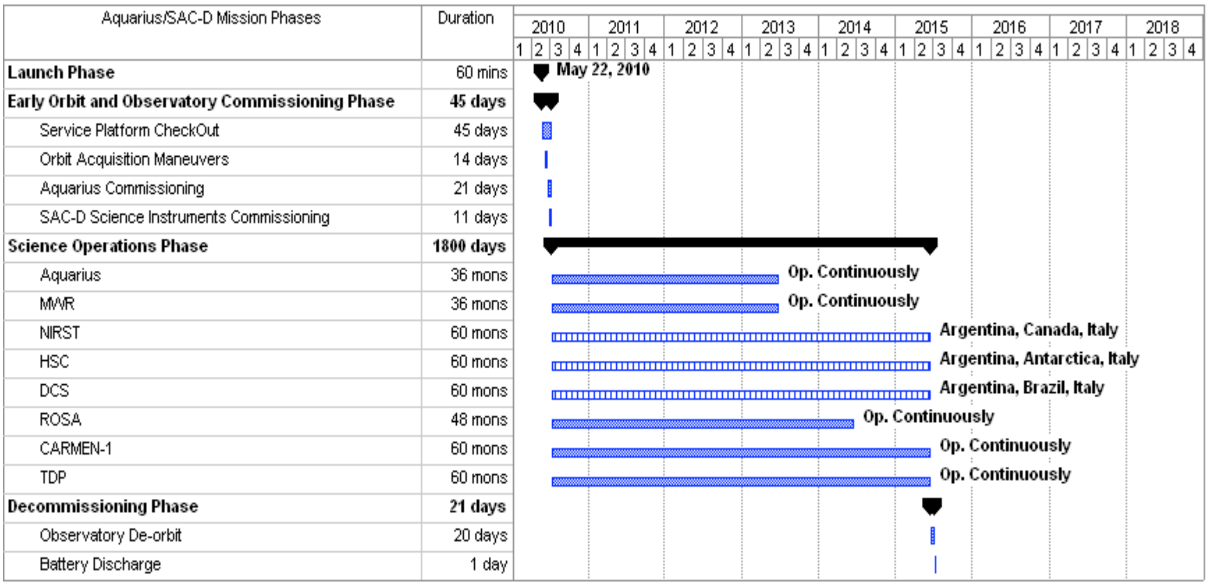


Figure 2-5 Mission timeline

3.0 System Description

The systems required to accomplish the Aquarius/SAC-D mission include: the Launch Vehicle, the Flight System (S/P and Science Instruments) and the Ground Segment.

3.1 Launch Vehicle

The Launch Vehicle (L/V) selected for the Aquarius/SAC-D mission is a DELTA II 7320. The 7320 Delta II L/V would include the specific items to accommodate the Aquarius/SAC-D Observatory interface and mission design.

3.1.1 Configuration

The specific L/V configuration (see Figure 3-1) for the Aquarius/SAC-D mission is composed as follows:

- First Stage:
  - Three (Ø 40”) strap-on solid propellant rocket motors
  - Standard Delta II Core, RS-27A engine

- Second Stage:
  - Standard Delta II second stage; AJ10 engine
  - Redundant Inertial Flight Control Assembly (RIFCA)

- Payload Accommodations:
  - 3 meter (10.0 ft) diameter composite Payload Fairing (PLF)
  - Three 24” diameter payload fairing doors.
  - Two 37 Pin/Socket Umbilical connectors (disconnected at PLF separation)
  - 6306 Payload Attached Fitting (PAF)

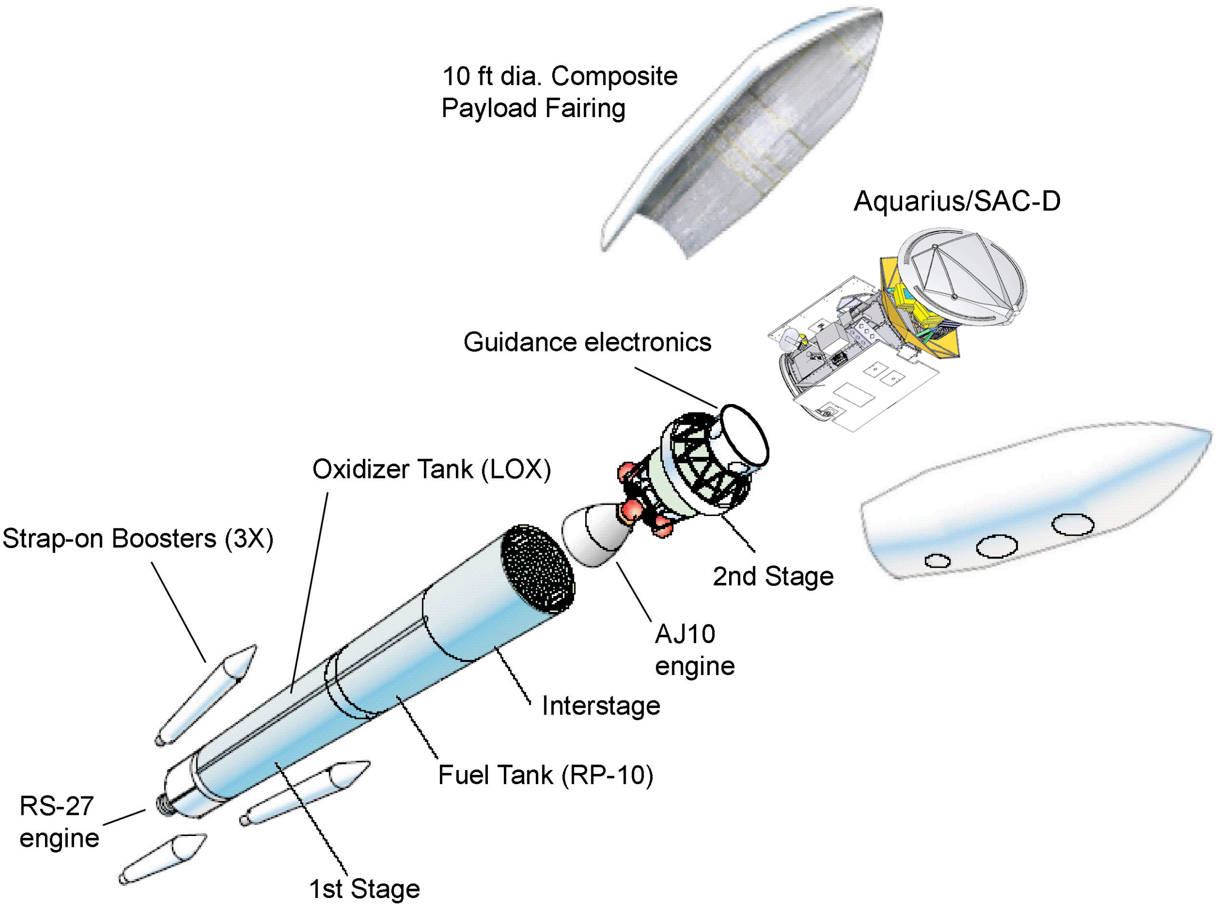


Figure 3-1 Delta II 7320-10 L/V configuration

The Strap-on solid propellant rocket motors provide added boost capability during liftoff. These motors are equipped with ordnance thrusters and the Inadvertent Separation Destruct System.

The AJ10 engine powers the storable propellant, restart-able second stage. This stage utilizes the Redundant Inertial Flight Control Assembly (RIFCA) guidance and navigation system. This is a key second-stage component which provides guidance and control for the rocket resulting in the precise payload deployment that is associated with Delta II launch services.

The PLF encloses the second stage and payload during first stage flight and the early portion of second stage flight.

The 6306 PAF is the interface that is used to secure/release the Aquarius/SAC-D Observatory to the Delta II L/V. The 6306 PAF includes the following features:

- Clampband
- Three secondary release latches
- Accommodations (switch pads) for four separation detection Observatory switches.

The secondary release latch system is implemented in order to reduce the tip-off rate induced by the release of the clampband. No separation springs are required.

3.1.2 Launcher Coordinate System

The definition of the coordinate system clocking used by the Delta II L/V is shown in Figure 3-2:

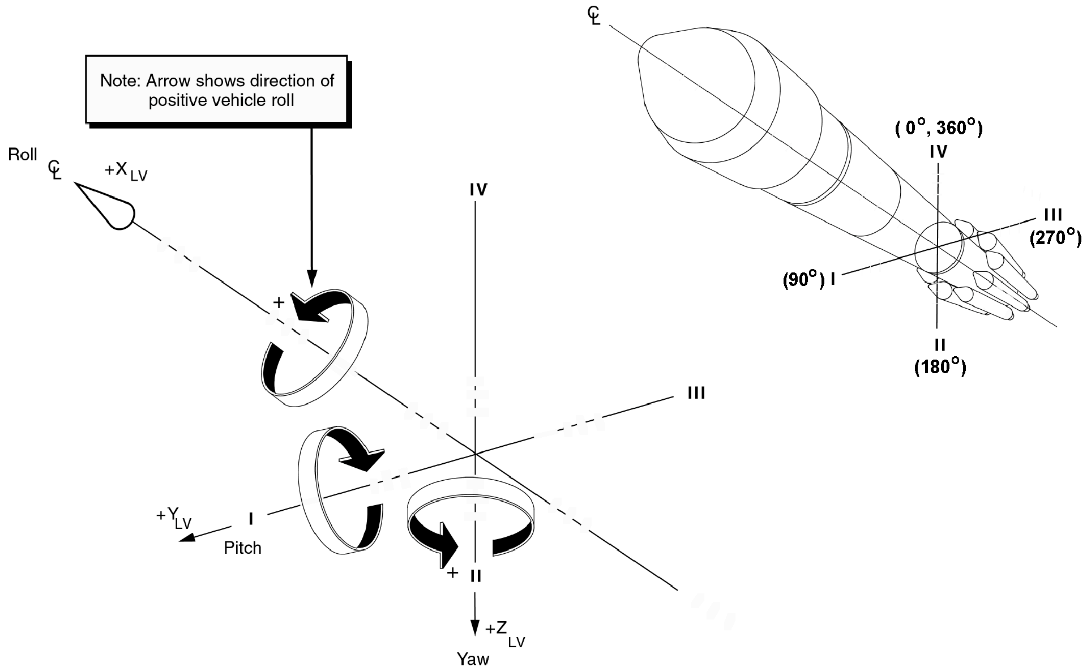


Figure 3-2 L/V coordinate system

During powered flight, ***the L/V Quadrant II is pointed facing nadir***, i.e. pointed toward the Earth.

3.1.3 Clocking

The relationship between the L/V (X_{LV}, Y_{LV}, Z_{LV}) and the Observatory (X_{SC}, Y_{SC}, Z_{SC}) coordinate systems (*clocking*) is defined in Table 3-1 and Figure 3-4. This particular mounting orientation of the Observatory on top of the L/V was selected in order to keep the sun on the $+Z_{SC}$ side of the Observatory (away from the battery radiator) during the powered portion of the flight.

Aquarius/SAC-D Spacecraft (SC) Axis	Launch Vehicle Clocking (1)
$+X_{SC}$	20°
$+Z_{SC}$	290°
$+Y_{SC}$	

Spacecraft Axis System Origin
Y_{SC} = 0.0 cm at X_{LV} STA = 1255.3 cm (494.21 inches) X_{SC}, Z_{SC} = 0.0 cm at Y_{LV}, Z_{LV} = 0.0 cm
(1) The launch vehicle clocking (degrees), to SAC-D from QIV, is defined as: QIV = 0°/360° (-Z_{LV}), QI = 90° (+Y_{LV}), QII = 180° (+Z_{LV}), QIII = 270° (-Y_{LV})

Table 3-1 Observatory to L/V coordinate system

The spacecraft coordinate system frame is centered on the observatory centerline and is 0.0 cm (0.0 inches) at the Observatory/PAF separation plane.

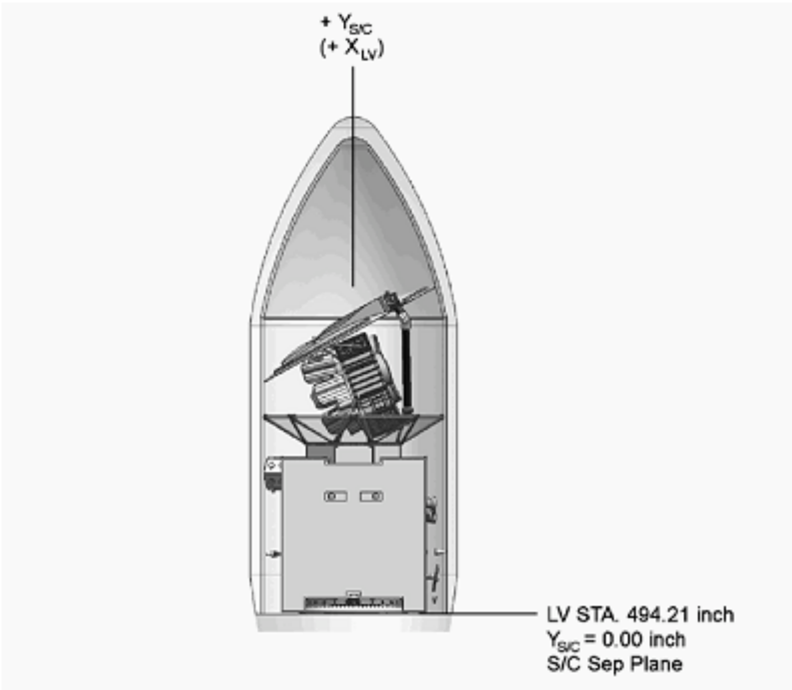


Figure 3-3 view from one side

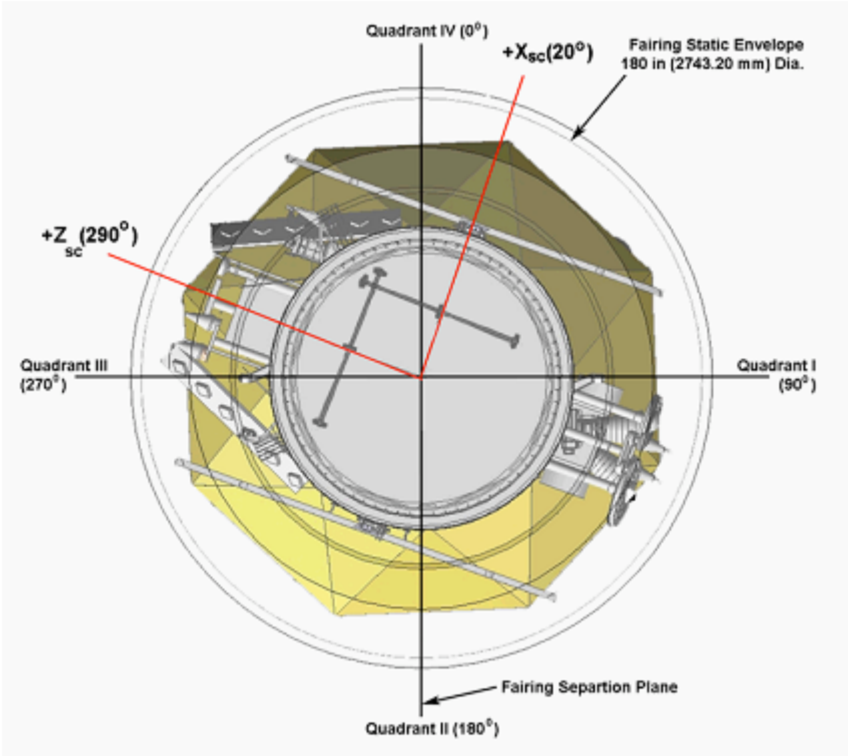


Figure 3-4 View looking forward ($+X_{LV}$, $+Y_{SC}$) direction

The bottom surface of the Observatory at the Separation Ring is the Aquarius/SAC-D origin of coordinates (L/V Station 494.21 inches). The Y_{SC} axis is parallel to the long axis of the observatory, along the velocity vector of the L/V (X_{LV}).

3.2 Flight System

The entire flight system placed in orbit by the L/V is called the Observatory (see Figure 3-5). The Observatory is a three axis stabilized, earth pointing, low earth orbit scientific satellite consisting of the Aquarius instrument (NASA provided) and the SAC-D S/P and instruments (CONAE & international partners provided).

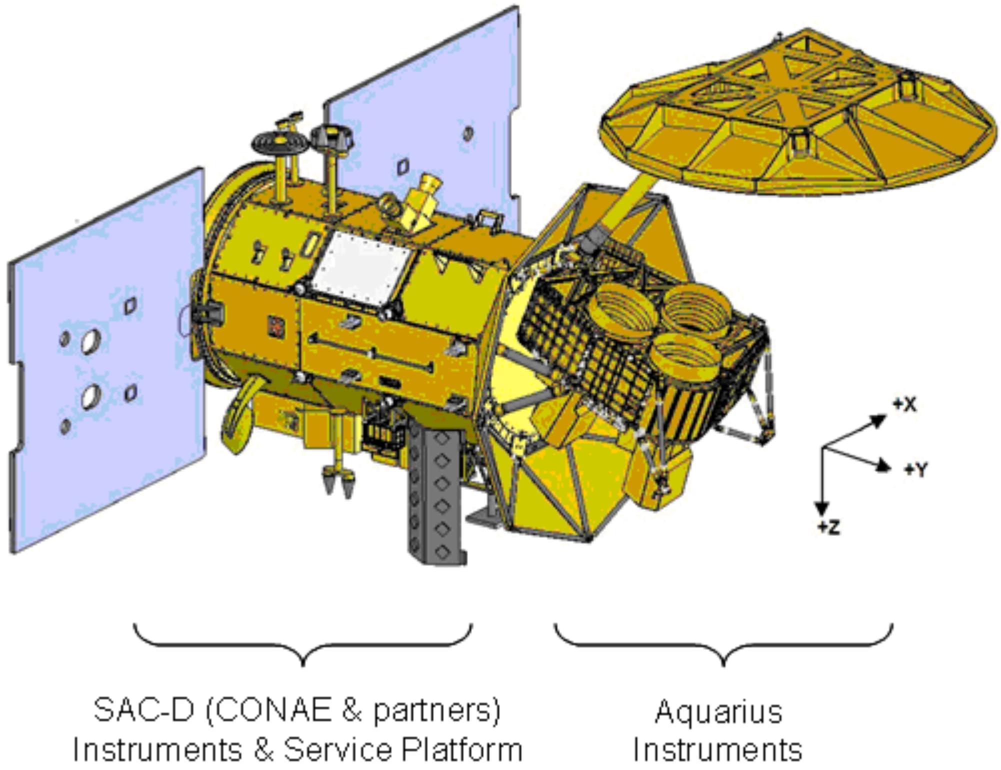


Figure 3-5 Observatory

The Observatory in launch configuration is a right octagonal shaped spacecraft approximately 2.7 m across and 2.5 m tall without the Aquarius instrument and with it almost 5 m tall. The Aquarius instrument is located at the top of the S/P. The bottom of the satellite incorporates two diametrically opposed hinges that support the spacecraft solar array, which consists of two identical wings approximately 2.2 m tall and 2.15 m wide. The total launch mass of the spacecraft including fuel is not to exceed 1675.0 Kg.

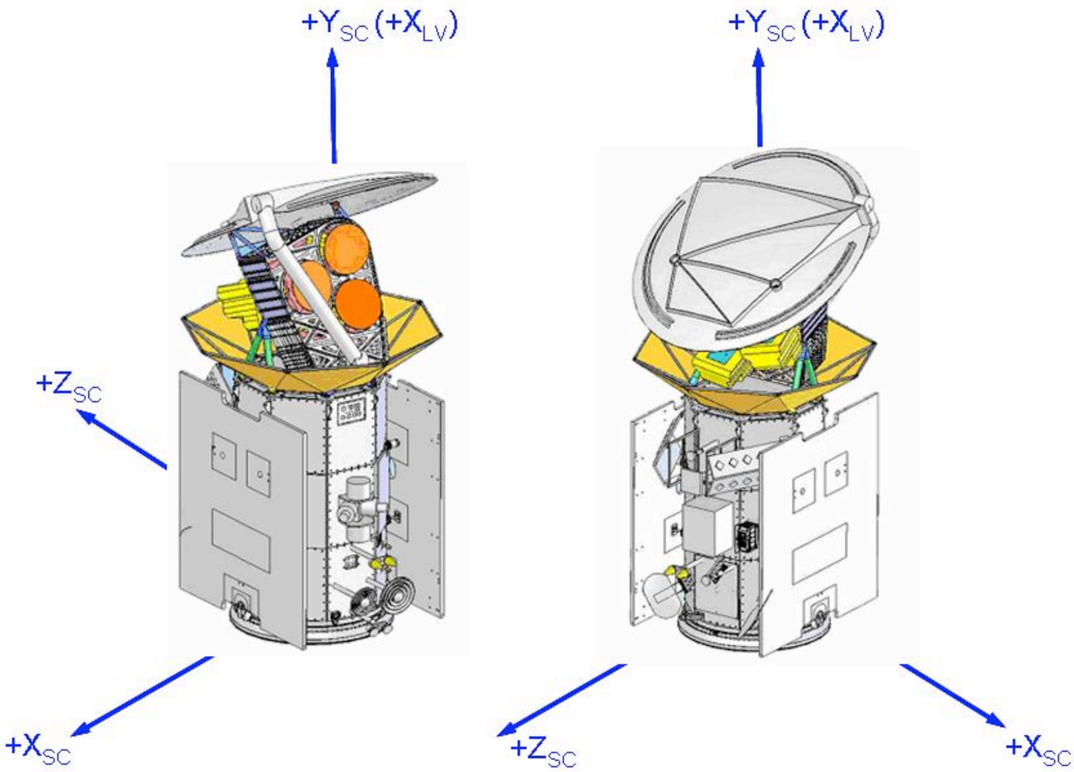


Figure 3-6 Aquarius/SAC-D in the launch configuration

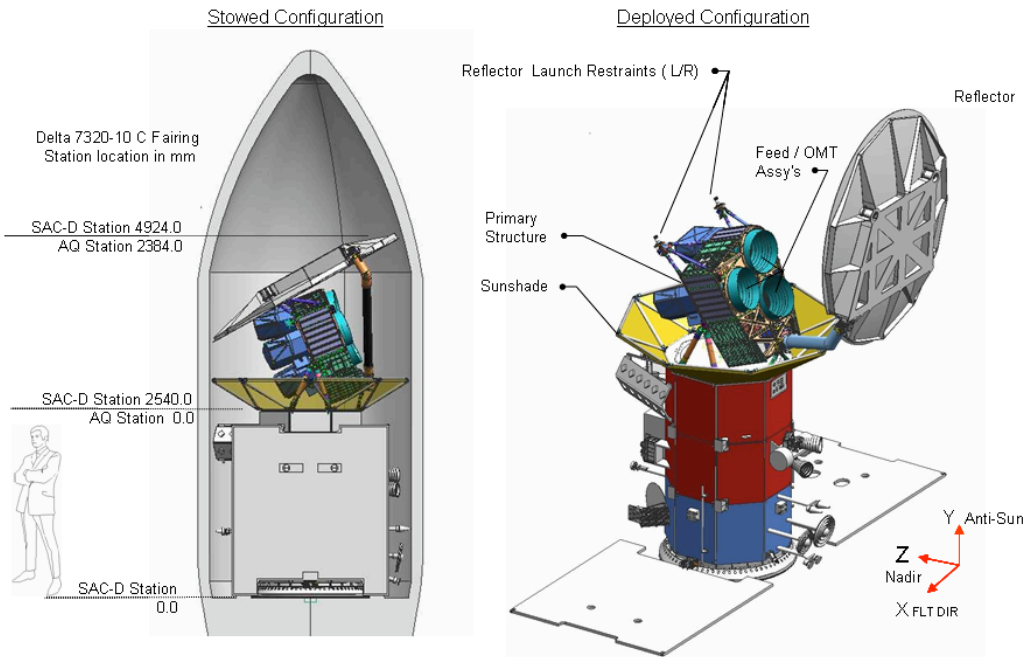


Figure 3-7 Spacecraft configurations

3.2.1 Service Platform

The Aquarius/SAC-D S/P has the following subsystems and assemblies:

- Structure and Mechanism Subsystem
- Attitude and Orbit Control Subsystem
- Command and Data Handling Subsystem
- Electrical Power Subsystem
- Communications Subsystem
- Propulsion Subsystem
- Thermal Control
- Mass Memory
- Data Acquisition and Processing Subsystem

3.2.1.1 Structure and Mechanism Subsystem

The Structure Subsystem’s basic function is to provide mechanical support for all SAC-D subsystem equipment hardware and for the scientific payloads in order to withstand the ground, launch and orbit environments.

The shape of the platform structure of SAC-D spacecraft is shown in Figure 3-8 and its main dimensions in Figure 3-9. This shape was chosen after the SAC-C heritage requirement. It has an octagonal cross section; it houses the majority of the subsystem equipment inside, is attached onto the launcher at the bottom and has allocated on top and on the side covers the scientific instruments.

Structure and Mechanism Subsystem can be divided into three groups:

- Primary structure;
- Secondary structure;
- Mechanical assembly hardware.

The primary structure provides support for the different equipment of the platform, the connection with the launcher and the mechanical support for the scientific payloads and for the solar panel.

The constituents of the primary structure are:

- A bottom Payload Attachment Fitting that provides the structural interface with the L/V;
- Four all aluminum Honeycomb type platforms;
- An independent aluminum frame around each platform;
- Columns on the eight corners of the structure;
- Eight sides covered by lateral panels attached to the frames and columns;
- Battery frames.

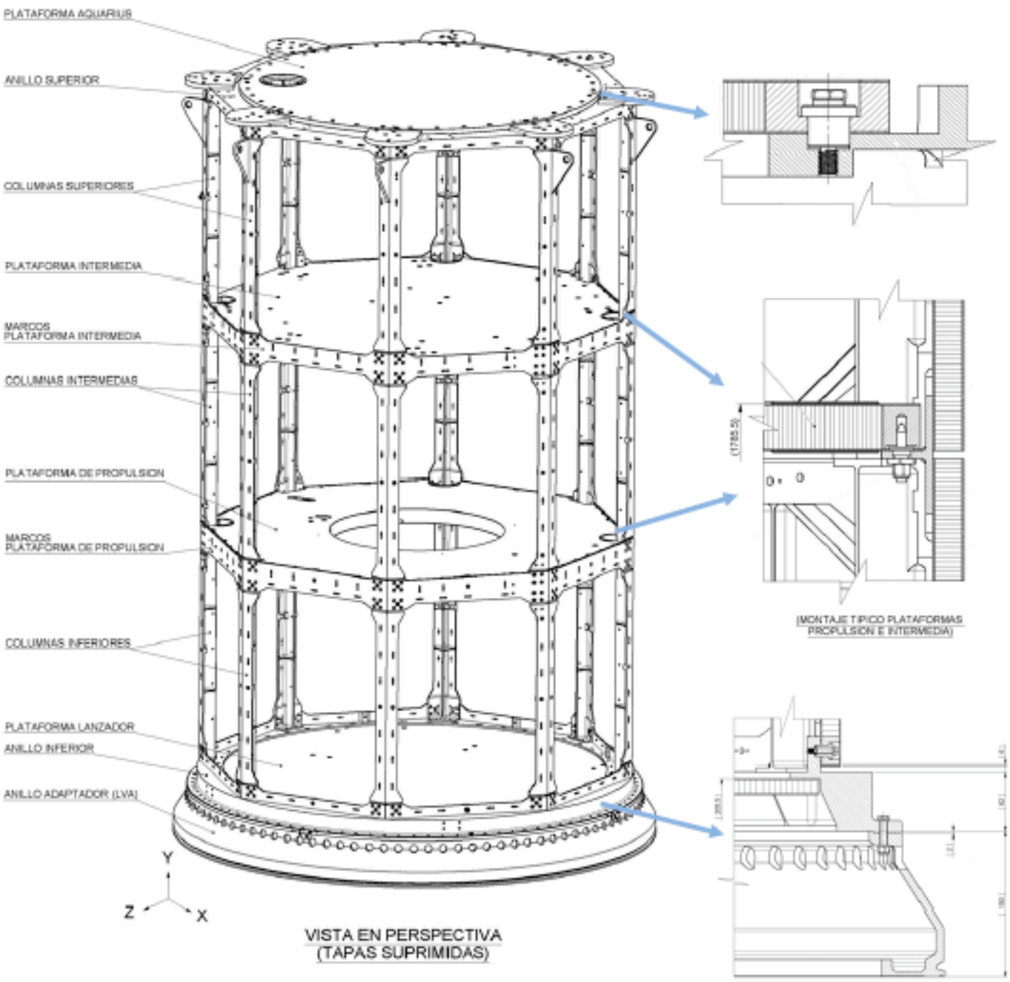


Figure 3-8 Service Platform columns, frames and Platform views

The secondary structure allows the mounting of some units of the S/P subsystems and consists of:

- Four reactions wheel supports;
- Hydrazine tank support;
- Radio Frequency antenna;
- Piping and thruster support;
- Battery frame supports;
- GPS antenna support, etc.

The mechanical Assembly Hardware includes bolts, inserts, washers, nuts and all required parts to assemble the structural components. All these elements are made of light nonmagnetic alloys and structural elements are either bonded or assembled by means of nonmagnetic qualified material.

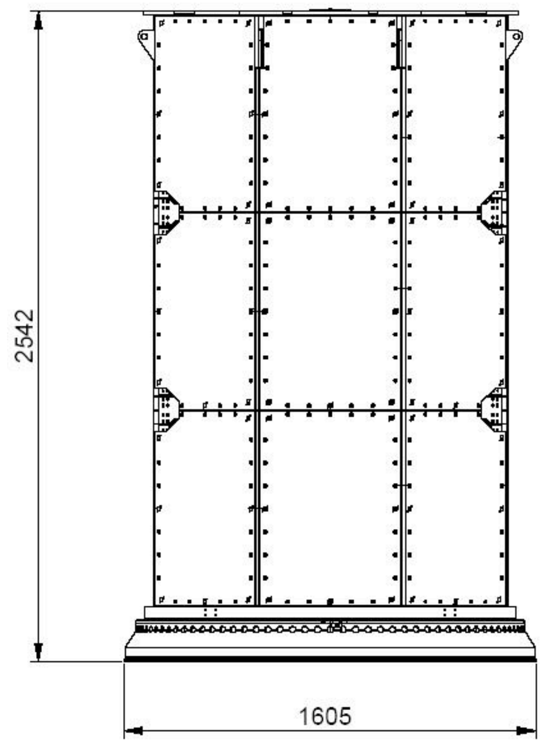


Figure 3-9 Service Platform external dimensions (in mm)

3.2.1.2 Attitude and Orbit Control Subsystem

SAC-D will be an earth oriented, three axis stabilized, zero momentum spacecraft. The reference frame will be the Local Vertical Local Horizon frame (LVLH) defined as follows:

- Zr axis (yaw) pointing along the local nadir
- Yr axis (pitch) pointing along the negative orbit normal
- Xr axis (roll) completes the right handed triad.

The control objective is to maintain angular deviations and rates of the spacecraft control frame Xc,Yc,Zc with respect to the reference frame Xr,Yr,Zr within specified limits.

The attitude determination will be based on standard filtering algorithms using information provided by several sensors and the attitude control will be performed using a combination of actuators.

The Attitude and Orbit Control Subsystem (AOCS) is composed by the following set of sensors and actuators:

SENSORS

- 12 Coarse Solar Sensors
- 2 Four-Axis Magnetometers

- 2 GPS
- 2 Star Sensors
- 2 Three-Axis Gyro Units

ACTUATORS

- 4 Momentum Wheels (1 redundant)
- 3 Torque-Rods (single Core with two Coils)
- 8 Thrusters (two independent branches)

SAC-D mission will implement the following attitude control modes:

- Stand by Mode
- Survival Mode
- Safe Hold Mode
- Science Mode (Inertial and Yaw Steering)
- Propulsion Mode

The safest modes are based on the simplest and unrestricted field of view sensors and simplest algorithms (not dependence on any attitude determination to all the possible extent). The safe modes will be thermal and power stable for unlimited time without need of ground support.

- The ***Stand by Mode*** is a transitory mode at AOCS computer reset or Power ON. It is the AOCS mode after Power ON until Spacecraft separation from the launcher. All sensors provide telemetry. No commands are sent to the actuators

- The ***Survival Mode*** is the simplest attitude mode. It does not require any attitude determination. The -Y spacecraft axis is pointed to sun and the spacecraft will be maintained rotating along the -Y axis at an inertial rate of around twice the orbital rate. The main sensors for this mode are the Coarse Sun Sensor and the three axes Gyro. The actuators will be reaction wheels and magnetic torque coils to de-saturate the wheels.

- The ***Safe Hold Mode*** is the simplest mode with rough attitude close to nominal. A rough three axis attitude is calculated using the coarse sun sensor and the magnetometer. Orbital propagation and on board time are necessary in this mode. The body rates for damping and control stabilization are sensed by the three axes Gyro. The actuators will be reaction wheels and magnetic torque coils to de-saturate the wheels.

- The ***Science Mode*** is the nominal mission mode. The Observatory will enter this mode only under Ground Command. The attitude will be estimated through an extended Kalman filter using gyros and updates from star sensors. The position data for inertial to orbital attitude transformation will be provided by the GPS navigation solution. In addition, an on-board orbit propagator will provide position data, for the case of GPS momentary unavailability. The reaction wheels will be the primary actuators. The on-board angular momentum will be maintained around zero or a very low value. The momentum wheels will be de-saturated using magnetic torque coils. This mode will be also used to perform the Cold Sky Calibration maneuver (pitch rotation).

In the Science mode, the Observatory will implement two operational attitude modes: Inertial Steering and Yaw Steering.

- ✓ **Inertial Steering**
  +Z-axis in the local Nadir direction (geodetic Local Vertical),
  +X-axis aligned with the Local Horizontal contained in the orbit plane (defined by the instantaneous position and inertial velocity) and in the sense of the velocity,
  +Y-axis completes a right-handed orthogonal system, pointing in the anti-sun direction.

- ✓ **Yaw Steering** (nominal Science Mode)
  +Z-axis in the local Nadir direction (geodetic Local Vertical),
  +X-axis aligned with the Local Horizontal contained in an artificial "ground" orbit plane (defined by the instantaneous position and ground velocity) and in the sense of the velocity,
  +Y-axis completes a right-handed orthogonal system, pointing in the anti-sun direction.

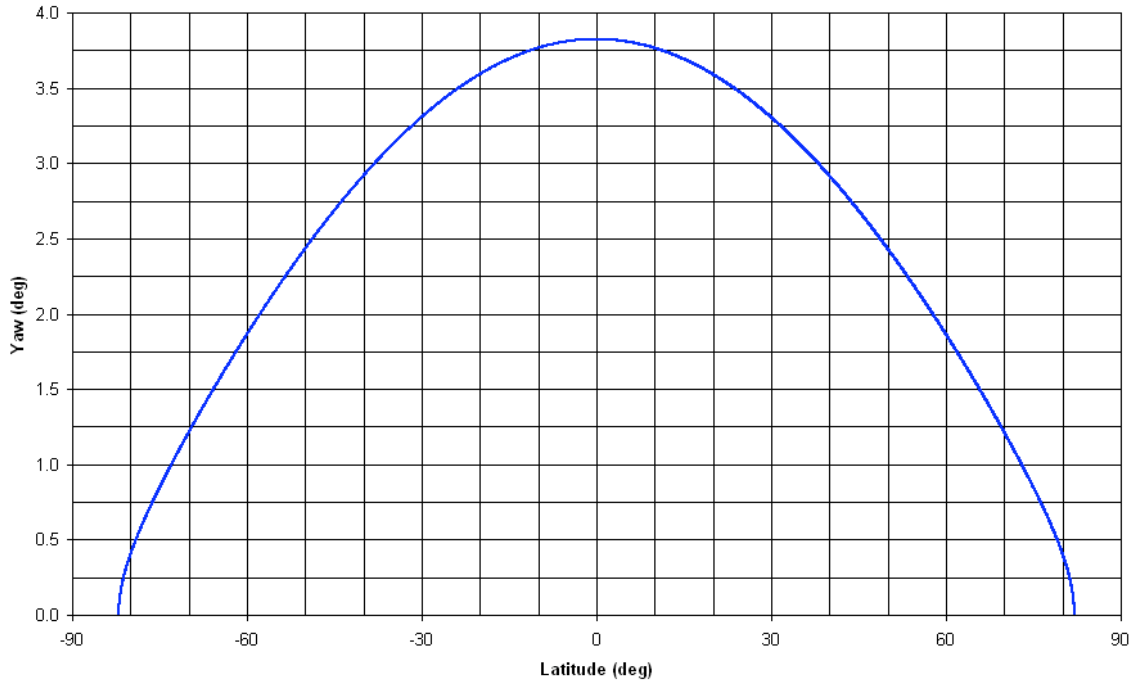


Figure 3-10 Yaw angle (absolute value) vs. Latitude

- The ***Propulsion Mode*** will be used for orbital corrections. The thrust vector will be along the +X spacecraft axis. If any previous attitude maneuver is necessary to direct the thrust vector along other direction (i.e. orbit inclination correction), it will be done with reaction wheels before entering the propulsion mode. The same applies for returning to the initial attitude after thrust. Once in the propulsion mode (during thrust), the attitude will be closed loop maintained by the same thrusters, by off-pulsing the necessary ones. If any attitude angle trespasses a limit, the thrusters are disabled and a transition to safe hold mode is done automatically.

Figure 3-11 shows the transition diagram between AOCS modes. Transition from more complex to safer and simpler modes can be performed either automatic from on-board diagnostic or through ground command. Transition from safer to more complex modes will be always ground commanded.

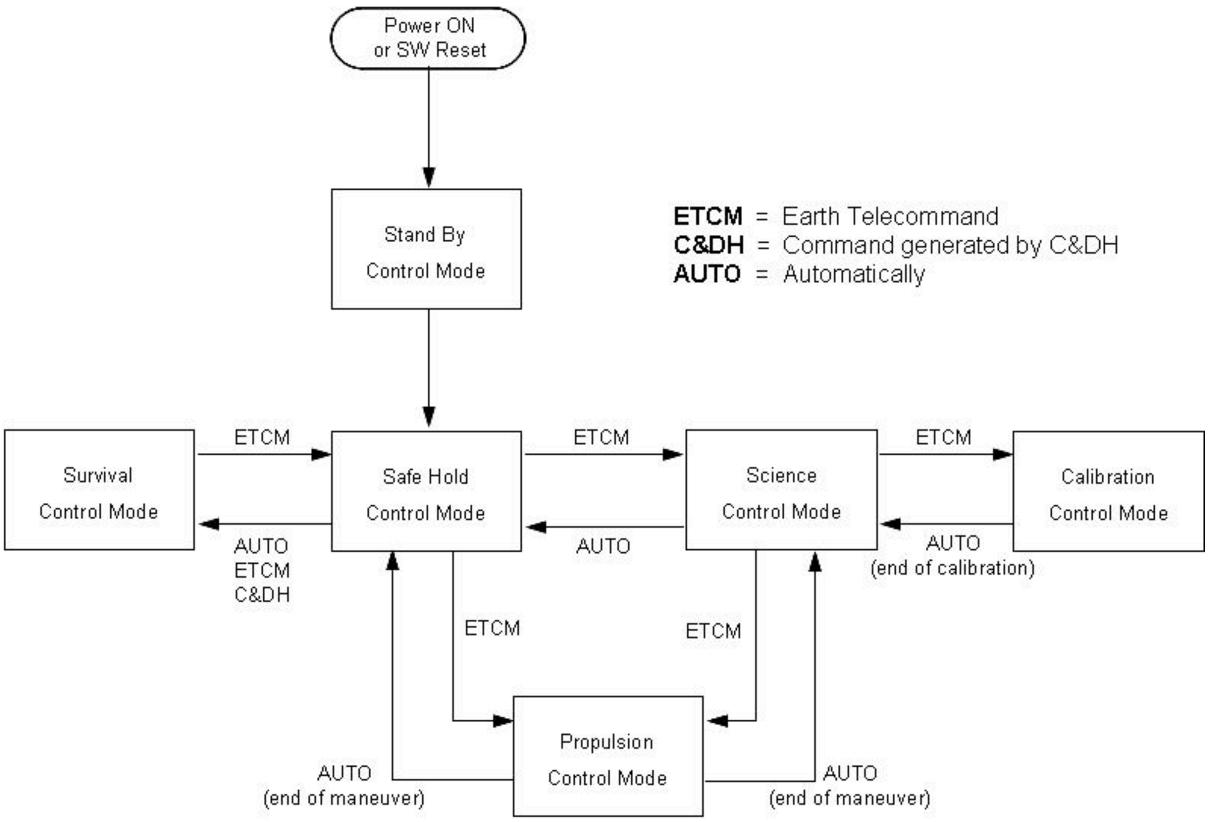


Figure 3-11 Transition between AOCS modes

3.2.1.3 Electrical Power Subsystem

The SAC-D Power Subsystem is designed to provide the satellite with its electrical power needs throughout its mission life. The power generation capability provided by the solar array is 1352 W @ 34.5 V (EOL). The power subsystem main components are:

- The Power Control Electronics (PCE)
- Remote Terminal Unit (RTU)
- Battery Management Unit (BMU)
- Voltage Regulator (VREG)
- Pyrotechnic Firing Box
- Battery

- Solar Arrays (two wings)

The Power Control Electronics (PCE) functions are: to receive commands from C&DH, validate and execute received commands, execute all power subsystem control algorithms, execute the battery management algorithm, execute thermal control algorithm, gather RTU, BMU and VREG telemetry, send commands to the RTU, BMU and VREG, execute health tests, update the subsystem telemetry frame and send it to C&DH upon request.

The Remote Terminal Unit (RTU) functions are: to receive commands from the PCE, validate and execute received commands, distribute power to the essential and non-essential loads, measure essential and non-essential loads current, protect the main power bus from short circuits in the loads, measure primary (main power bus) voltage, measure secondary voltages, measure temperatures, provide digital inputs and digital outputs, generate telemetry and send telemetry to the PCE upon request.

The Battery Management Unit (BMU) functions are: to receive commands from the PCE (these functions are shared with the VREG), validate and execute received commands (these functions are shared with the VREG), measure battery temperatures, measure battery voltage, measure battery cell voltages, measure battery current, measure battery cell pressures, generate telemetry (these functions are shared with the VREG) and send telemetry to the PCE upon request (these functions are shared with the VREG).

The Voltage Regulator (VREG) functions are: to receive commands from the PCE (these functions are shared with the BMU), validate and execute received commands (these functions are shared with the BMU), provide battery charge control, regulate the power bus voltage, measure solar array currents, generate telemetry (these functions are shared with the BMU) and send telemetry to the PCE upon request (These functions are shared with the BMU).

The Pyrotechnic Firing Box contains a relay, a fuse and the relay coil driver. Its functions are: to provide Aquarius Instrument pyrotechnics firing interface and circuitry, fire pyrotechnics after firing command from an RTU and enable from C&DH have been received and prevent accidental firing.

The 120 Ah Lithium-Ion battery supplies power to the observatory during eclipse and whenever power consumption exceeds power generation from the solar array.

The solar Arrays (two wings) generate all power required by the observatory. They also provide the mounting frames to coarse solar sensors.

3.2.1.4 Propulsion Subsystem

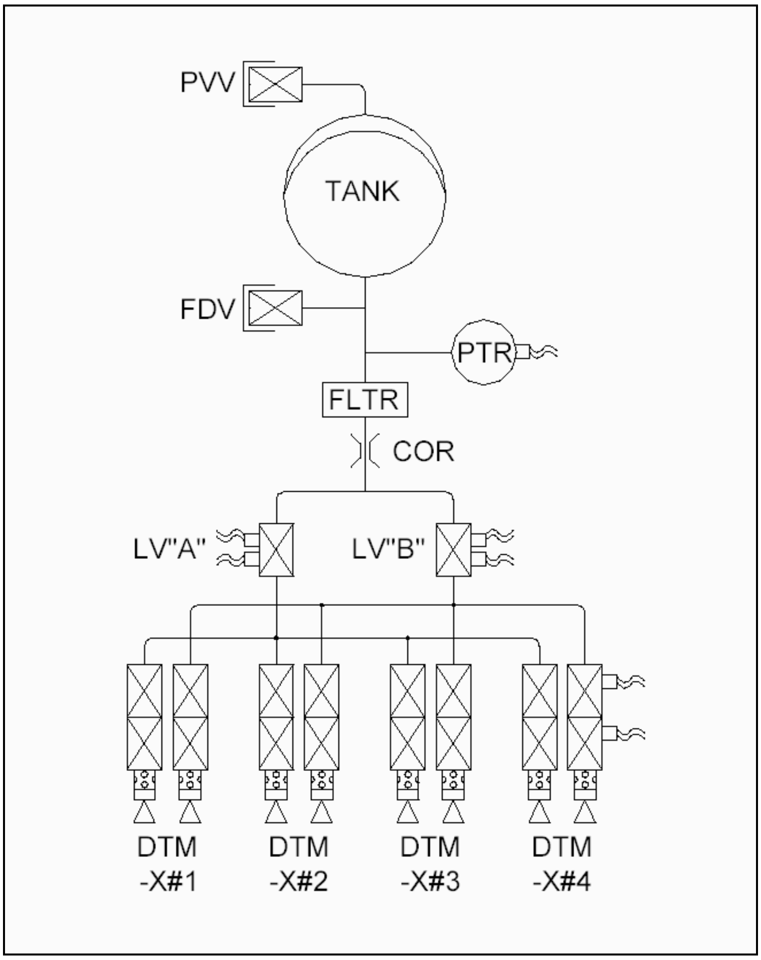
The Propulsion subsystem will be used for injection error correction in altitude and orbit plane inclination and for the subsequent orbit maintenance. It is also used for the de-orbit maneuver, which is necessary to avoid having the spacecraft to remain in space for a period longer than 25 years, once the mission is over.

SAC-D propulsion subsystem is a monopropellant type blow down system. These types of systems are more reliable than regulated ones due to their simplicity, despite the thrust diminution during the mission due to the tank pressure decay. Other reason for this selection is a good performance/weight relation and the SAC-C heritage. The propellant used by the system is ultra high purity (UAP) monopropellant hydrazine (N2H4), pressurized with nitrogen (N2) through an elastomer diaphragm. This subsystem has the following components:

- 1 diaphragm tank
- 1 fill and drain valve
- 1 press and vent valve
- 1 pressure transducer
- 1 system filter
- 1 calibrated orifice damper
- 2 isolation latching valves
- 4 dual thruster modules
- Stainless steel welded lines and manifolds

The tank selected by CONAE for this mission is the PSI P/N 80298-1 with the structural mounting lugs of PSI P/N 80388-1. It has an internal elastomer diaphragm to separate the propellant (hydrazine) from the pressurizing agent (gaseous nitrogen). This tank has a maximum operational pressure of 485 psi (33.4 bar), an internal volume of 91 liters and a qualified volume for propellant of 77.9 liters. With this amount of hydrazine, the blow-down ratio is 7.

Each dual thruster module consists of two thrusters mounted and aligned in the same plate. One thruster belongs to one redundant branch and the other one to the other branch. Each thruster has two series valves, which have to be separately energized to let the propellant flow through and reach the catalyst bed. The valves have thermostatic switched heater lines and temperature sensors (PT2000) to control the valves temperature within specified limits. Each catalytic bed has heaters to avoid cold starts and a thermocouple type temperature sensor to know the engine temperature at any moment. After fueling the propellant temperature and pressure are continuously monitored even with the satellite powered off.



3.2.1.5 Thermal Control Subsystem

The Thermal Control Subsystem has the function of maintaining the SAC-D S/P and all its subsystems, components and equipment within their operative range of temperatures specified in the Allowable Flight Temperature (AFT) and Thermal Test Temperature Requirements.

This subsystem is designed to use both passive and active temperature control capabilities to maintain S/P subsystems operational temperature ranges and mission interface temperature ranges of the science instrument for nominal mission operations.

The thermal control subsystem is implemented using:

- Electrical heaters
- Radiator surfaces
- Temperature sensors
- Thermostats (bimetal type)
- Thermal blankets
- Isolation products (G10, etc)
- Doublers (made of aluminum, copper, etc)
- Thermal gaskets (Silicone RTV-566, etc)
- Paints, coatings

The science instruments will be responsible for maintaining instrument-operating temperatures. Every instrument provides an ICD containing all data of its interfaces (thermal, mechanical, electrical, etc.) with the S/P.

In the S/P, we can distinguish three main thermal rooms:

- The Battery Room (AFT from -15°C to 0°C, measured on the base-plate. AFT denotes the Allowable Flight Temperature)
- The Propulsion Room (AFT from +10°C to +40°C, measured on components that can be in contact with hydrazine)
- The Main Room, where general electronic boxes are attached (AFT from -10°C to +40°C, measured on platforms and lateral panels).

Separation between thermal environments is achieved by mechanical isolation (to conduction) and thermal blankets (to radiation). These isolation elements are completely passive.

The electronic boxes in general and the battery dissipate heat toward deep space through radiators that are part of the S/P external surfaces. (Most of the electronic boxes are mounted on lateral panels which are used to radiate heat into deep space). Electric heaters and/or the heat generated by the equipment, when they are on, are used to balance the system and to control the temperature.

The Main Room includes most of the S/P structure, with all electronic boxes, etc. inside it. Heaters, strategically located, are used to control temperature in this ambient. A series of Pt-2000 temperature sensors distributed along the structure provide the information to characterize the thermal status of the S/P and to allow its active thermal control.

The Propulsion Room dissipates heat mostly toward the inner parts of the S/P, loosing it through thermal blankets and joints to the S/P structure. For the Propulsion Room there are redundant electrical lines, with thermostats, to feed the heaters that maintain the subsystem above +15°C (they operate when the Main Room is below that temperature). Every heater line has two serial connected thermostats to avoid closed failure of one of these switches; the redundant lines are in order to avoid open failure of one thermostat. The thermostats close at 15°C ± 2.2 °C and open at 21°C ± 2.2 °C. As there is no heat generation inside Propulsion Room its highest temp will be bellow 40°C, which is the Main Room maximum AFT.

In the case of the Battery, there is an active thermal control implemented with redundant lines to feed different heaters that are mounted on battery cells. Activation of the heaters is controlled by software that uses measurements provided by redundant Pt-2000 temperature sensors. As the battery is partitioned into two physically separated parts and a very exigent requirement of temperature uniformity exists for the 22 cells, the software will have the capability to equalize the temperature of both semi-batteries. Survival heater lines actuated by thermostats are provided to the Battery. Payloads that are insulated from S/P structure have survival lines fed by the Platform. The back face of the solar array has a convenient surface finish to radiate heat into space.

Thermostats are used in the different rooms as following:

- Battery Room: In this room lines with thermostats are for survival purpose. One line per half battery is available with two thermostats in series. A total of four thermostats are used in the battery.
- Propulsion Room: In this room the thermal control is completely implemented with thermostats. Two redundant lines with thermostats are dedicated to the hydrazine tank. Two lines for the valves module. Two lines for each dual thruster module (DTM; there are four DTM). And two lines for each one of four partitions of piping. Considering two thermostats per line, there are a total of 40 thermostats in the Propulsion Room.
- Main Room: For this room there is a preliminary consideration of using thermostats on some of the fourteen lateral panels that have heaters for control. Until now there are 28 heaters distributed on fourteen panels. Panels have one, two or three heaters installed, and some of them will be controlled by thermostats. A preliminary number of thermostats that may be used are 25.

3.2.1.6 Communications Subsystem

The Observatory Communications Subsystem consists of three communication channels: S-Band Uplink, S-Band Downlink and X-Band Downlink. The communications subsystem main components are:

- 2 S-Band Transceivers
- 4 S-Band Omni Antennas
- 2 X-Band Transmitters
- 2 X-Band Helix Antennas
- 2 X-Band Hybrid couplers

The three communications channels are divided into two subsystems:

- Telemetry and Command Channels (S-Band)
- Stored and Real Time Data Downlink (X-Band)

The Telemetry and Command Channels Subsystem (TCCS) is to provide communication between the mission platform and the Ground Segment in order to ensure the capability to monitor and control the spacecraft during all its mission phases.

The Downlink Data Science Subsystem (DDSS) is to provide communication between the Mass Memory Unit (MM Unit) and Ground Segment in order to ensure incoming data from the payloads (the Aquarius payload, the MWR payload, the MM Unit, the HSC payload, and the NIRST payload).

The Subsystem is to perform the following main functions:

- Transmission to ground of telemetry (TM) signal. The Subsystem receives the telemetry bit stream from the C&DH Subsystem, performs PSK and PM modulation of a carrier and transmits the RF signal to the ground stations. The transmission frequency can be either coherent mode with the received frequency (with a ratio of 240/221) or derived from a local oscillator.

- Reception of telecommand (TC) signal transmitted from a ground station. The Subsystem receives the RF TC signal, performs the PM and PSK demodulations and delivers a TC bit stream to the C&DH Subsystem.

The following figure shows the block diagram of the Telecommunications Subsystem at a basic level.

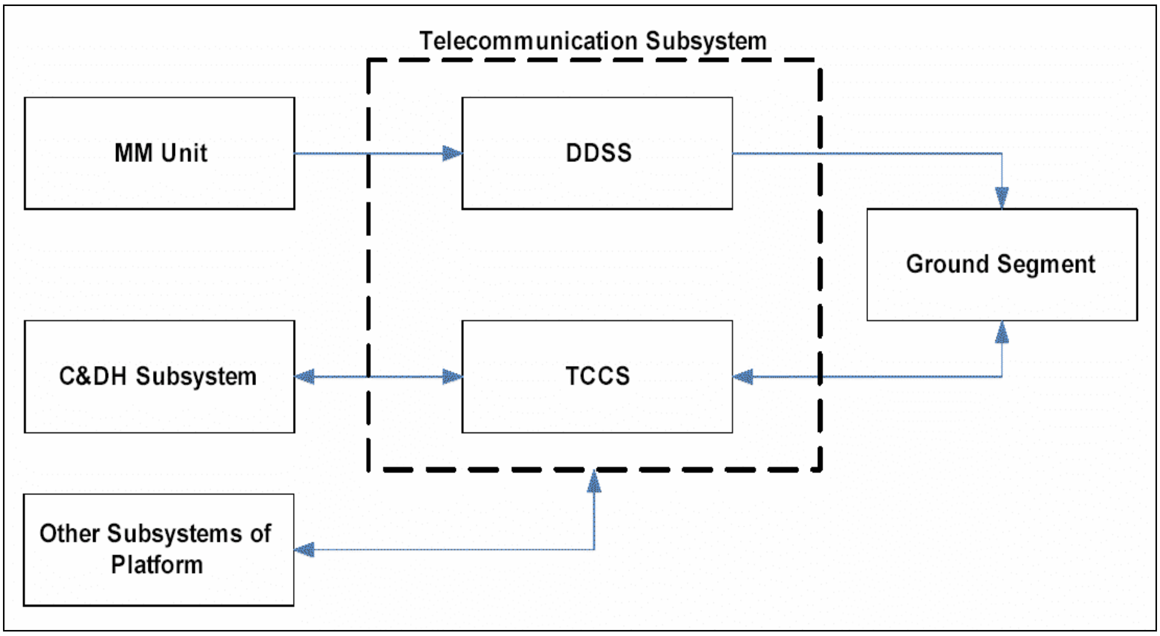


Figure 3-12 TT&C functional diagram

The main external agents of the Telecommunications Subsystem are the C&DH Subsystem, the MM Unit and Ground Segment.

3.2.1.7 Command and Data Handling Subsystem

The Command and Data Handling (C&DH) subsystem acts as ground command decoder and distributor for loads and subsystems, provides uplink command processing, stored command management, telemetry data collection and processing, autonomous fault protection, and subsystem intercommunications on the 1553 controller interface. It also monitors the state of the satellite and its instruments, and detects the release of the launcher and the unfolding of the solar panels.

The C&DH subsystem comprises two identical units (C&DH-A and C&DH-B) based on the 80C86 (radiation hard version) processor running at 4 MHz. These two units share the same SAC-C type box and work in Cold Back-Up configuration (one unit is on while other is off). Commutation between these units takes place as from a specially designed mechanism used in SAC-C, and may be automatic in the case of failure of the active unit, or through a hard command from ground station. See below a block diagram of the subsystem:

The subsystem receives non-regulated voltage (redounded) in the range of 20 to 40V from the primary power bus. This is an essential, redounded, and non-commutated load. It withstands an input over voltage of at least 40V. Only one C&DH will be on at the same time, e.g. C&DH-A or C&DH-B, never the two on or off. This is controlled by a subsystem inner board known as Relay ON/OFF. The Power consumption is 6 W.

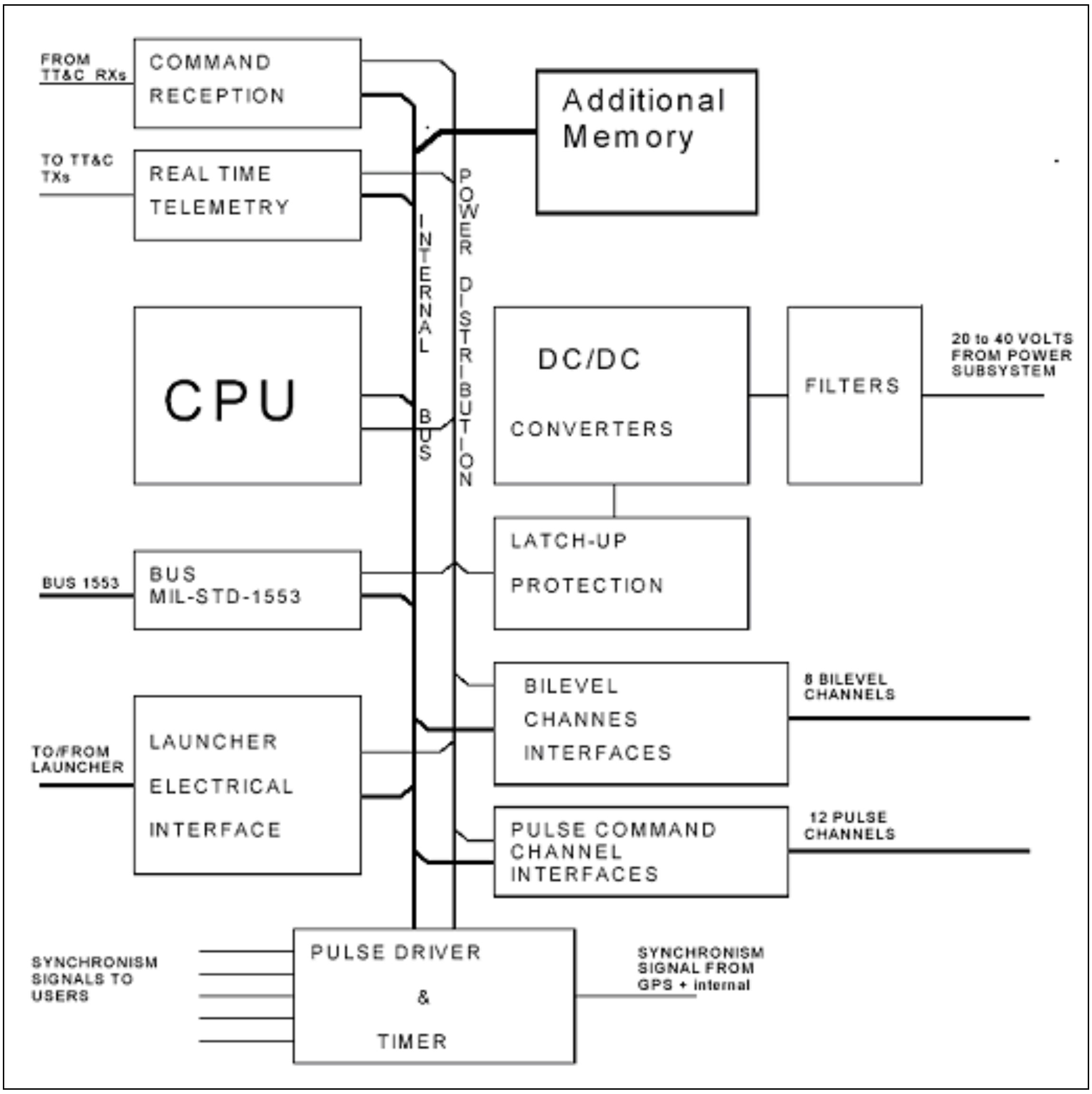


Figure 3-13 C&DH functional diagram

The C&DH unit that is currently on will be the bus controller of satellite network 1553, which has the rest of the subsystems and loads as remote terminals. The redundancy of this network implies that channel A and channel B of network 1553 reach C&DH-A, and these same channels reach C&DH-B. A long stub connection is implemented, due to which insulation transformers are included inside the C&DH,

and there must be transformers and coupling resistances to enter bus 1553, as specified by standard MIL-STD-1553.

C&DH-A receives the 1 Pulse per Second (1-PPS) Synchronization signals from the Bus GPS receivers 1 and 2 through a RS-422 interface. C&DH-B also receives them, the cross-strapping thus being achieved.

The C&DH unit that is currently on sends the 1-PPS synchronism signals to all subsystems and loads that so require it (it has a maximum of 12 outputs per C&DH). The falling edge is the synchronizing edge for the subsystems.

Each C&DH may read up to 8 inputs from passive switches. These inputs are used to monitor the status of the following parameters (TBC):

- Solar panel unfolding status
- Satellite release status
- Upper cone release status (TBC)
- Pyro unit relay status (TBC)

The RF interface implements the C&DH-TT&C transceiver connection. Each C&DH must feed both transmitters, while each receiver must feed both C&DHs. The interface comprises the following TTL logic signals (TBC):

- C&DH input signals: CLOCK – DATO - CARRY – SUBCARRY.
- C&DH output signals: CLOCK- DATO – ON/OFF

3.2.1.8 Data Acquisition and Processing Subsystem (PAD)

The PAD subsystem will realize part of the interface between the NIRST, MWR, DCS and ROSA instruments and the S/P. In particular, all these instruments will not have a direct 1553 interface with the S/P but via the PAD and they will not have a direct RS422 interface with the downlink but via the PAD. The thermal control algorithm for all these instruments will be implemented in the PAD computer. The memory storage requirement of these instruments will be satisfied by the PAD mass memory.

PAD subsystem is cold redundant and composed by two equivalent electronic boxes: PAD-A and PAD-B, each of them including the complete PAD functionality. Only one is powered by the RTU at any given time, being the selection made by Earth command. The stored information cannot be shared between units as they are never simultaneously operative.

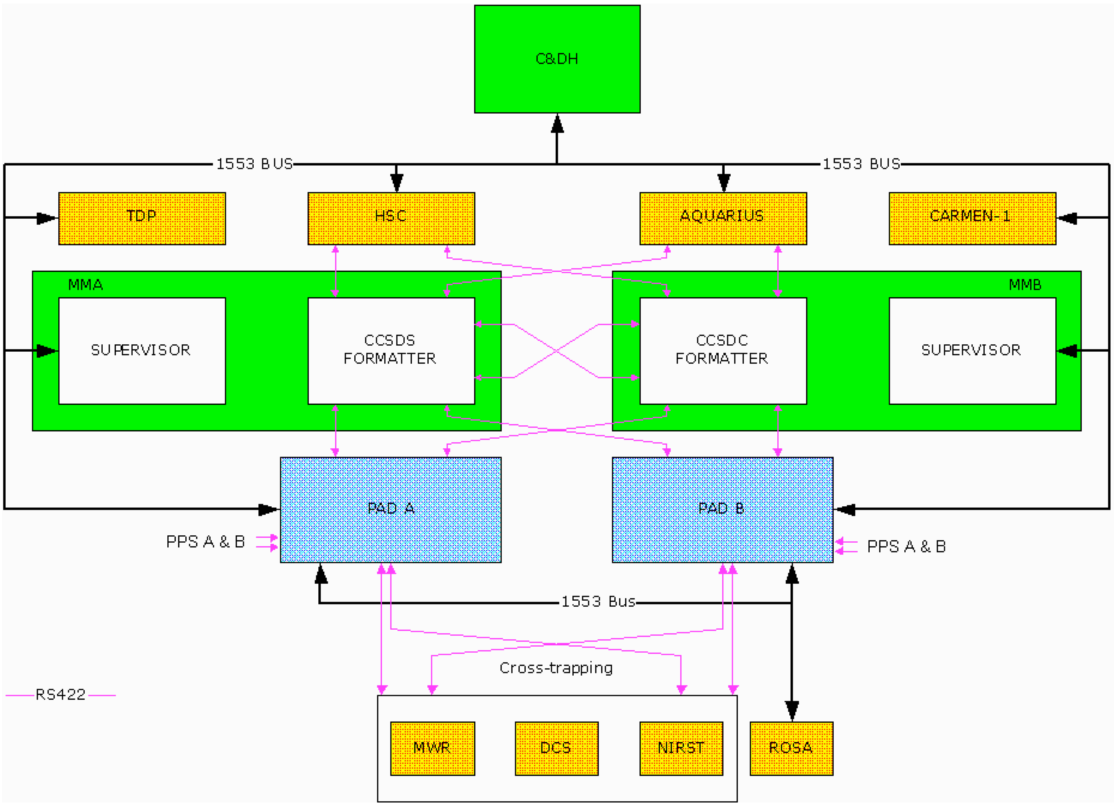


Figure 3-14 PAD functional diagram

The interface between PAD and the S/P include the following lines:

- GPS 1-PPS: from S/P to both PAD units.
- RTU power lines for PAD-A and PAD-B units.
- 1553 channel with the active CD&H computer of the S/P, being each PAD unit a different RT.
- RS-422 downlink channel from PAD-A/B to CCSDS-A/B in cross-trapping connection.
- Temperature and secondary voltage measurements lines from each PAD unit to the RTU.

The interface between PAD and the instruments is composed by:

- 1553 point to point channel with ROSA, being the powered PAD the Bus Controller
- RS-422 serial channels with DCS, MWR and NIRST. Cross-strapping is assumed for all of them but DCS.

3.2.1.9 Mass Memory Subsystem

The Mass Memory Subsystem (MMS) of SAC-D is a 256 MB storage unit, the main purpose of which is to store HK data, C&DH log file, and GPS raw data generated by the Observatory, as well as the science data generated by the CARMEN and the TDP instruments.

The Subsystem is fully redundant within the same box. The redundant units are fully independent, and their only connection points are the cross-strapping lines corresponding to the data sent to the X-band Download Transmitter (TX). Each MMU is assigned one TX, which is controlled by the corresponding unit. MMS is also in charge of formatting the data downloaded by the X-Band link, following the Advanced Orbiting System recommendation of the CCSDS. These data include those stored in the Mass Memory and the data generated by the Aquarius, MWR, NIRST, ROSA, DCS and HSC instruments and PAD maintenance files (logs, HK, configuration tables and status).

Table 3-2 provides a summary of the main characteristic of the MM units.

Memory technology	SDRAM (256Mbit)
Storage Capacity	256 MB
SEE error mitigation strategy	Triple Redundancy with voting logic
Number of boards	4 + Backplane
Associated transmitters per unit	1 (X Band)
Maximum download bit rate	20 Mbps
Output data bit rate	16Mbps typical (20 Mbps max.)
Input data rate in RS-422 dedicated channels	5 Mbps maximum

Table 3-2 Mass Memory characteristics

The MMU has the following Interfaces:

- MIL-STD-1553B redounded for communication with platform
- 6 RS-422 inputs (3 Data + 3 Clocks) for interface with instruments (AQ, PAD and HSC).
- 2 TBD output data channels (I and Q) towards the TX
- 1 TBD Clock channel towards the TX
- TBD signals for TX ON-OFF commands
- Input primary voltage: 28 V DC Nominal, range 18 V to 50 V DC
- 2 RS-422 inputs, 1 second pulse from the C&DHs
- Analogue outputs for internal voltage measurement towards the RTUs

The MMS is made up of two redundant and independent units, each comprising in turn the following:

- One Supervisor Module
- One Memory Module
- One CCSDS Data Formatter Module
- One DC-DC Converter Module

The Bus 1553 is used to receive the commands sent by C&DH and the data to be stored in the memory, and to send the telemetry of the subsystem to C&DH. The Supervisor Module operates as Remote Terminal of 1553 Bus. Each MMU has its own 1553 address, as the units may be independently powered on, and it is possible to have them running in Hot-Backup.

The Modules are connected to each other by means of an 8086 bus, and through full custom point-to-point signals. The 8086 bus is used by the Supervisor Module to configure the other modules and send the data to store to the Memory Module.

The Memory Module and the CCSDS Data Formatter Module communicate through serial lines. The CCSDS Formatter Module has dedicated inputs for the following instruments: Aquarius, PAD and HSC. As the block diagram shows (see Figure 3-15), the instruments have redundant lines reaching each MMU. The cross-strapping between MMUs is achieved through dedicated signals that exit from the CCSDS Formatter Module of one of the units and reach the CCSDS Formatter Module of the other, and vice versa. The output interface of CCSDS Formatter Module towards the transmitter is independent from the cross-strapping interface between MMUs. The transmitter command signals (ON, OFF, etc.) are controlled by the CCSDS Data Formatter Module.

Upon being powered on, each MMU will operate on one of the four possible modes, namely:

- Maintenance mode
- Normal mode
- MM Test mode
- Standby mode

The first two are the operating modes, while the MM Test mode allows establishing the quality of the X-band data link and the influence of different SEE types on SDRAM memories.

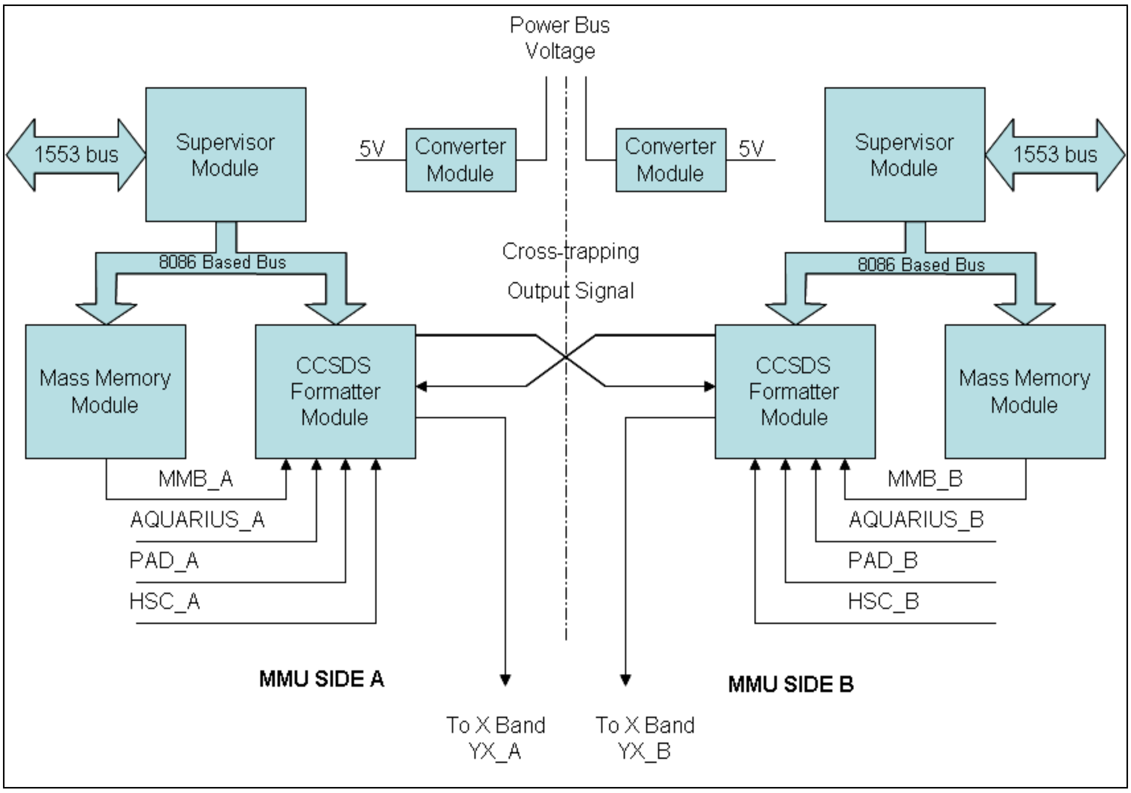


Figure 3-15 MMS block diagram

The Standby mode is the operation mode in which the unit will run upon detection of failures in critical components that prevent operation even with the minimum resources.

The operation mode at the moment in which the unit is powered on will depend on two circumstances:

- The information from the Reset source stored in a dedicated register
- The telecommand sent to the unit also stored in an internal memory

After a Reset, the Supervisor Module will indicate in telemetry the cause of such reset, the possible ones being the following:

- Power On Reset
- Watchdog Reset
- Software Reset

During normal subsystem operation, the operation mode may be changed only through a Change Mode Telecommand.

3.2.2 Science Instruments

3.2.2.1 Aquarius Instrument

The Aquarius instrument consists of six functional sub-systems: antenna, radiometers, scatterometer, command and data handling, mechanical and thermal, and power distribution. The figure below is a block diagram of the Aquarius instrument and the interfaces between these sub-systems.

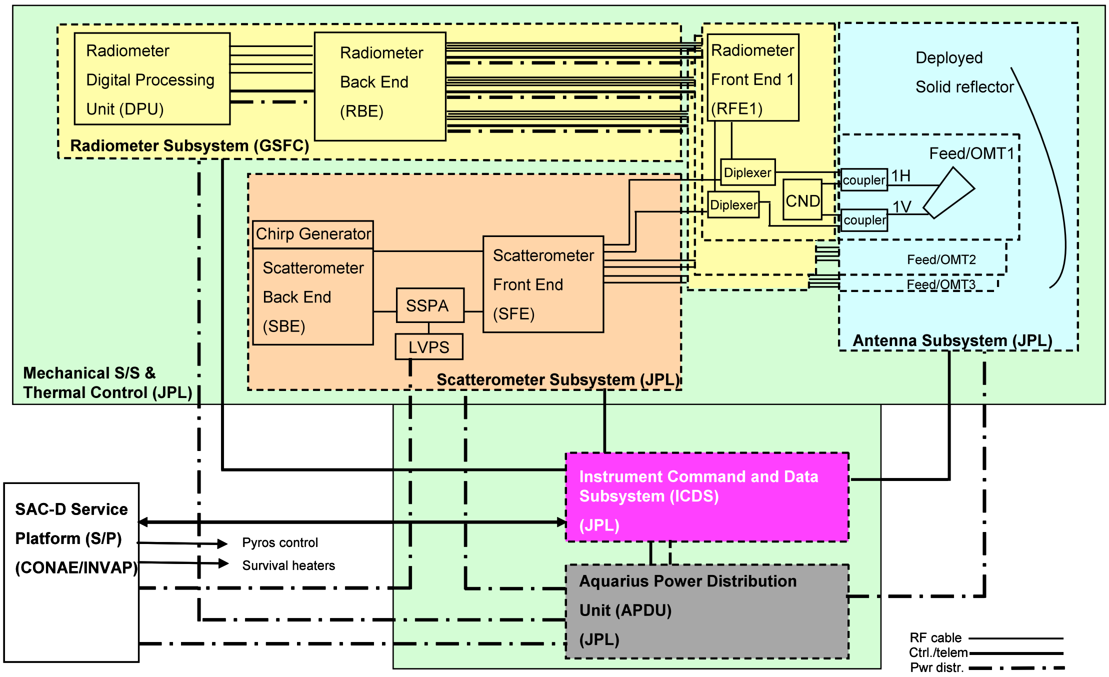


Figure 3-16 Aquarius Instrument Functional Block Diagram

The 2.5-m reflector is deployed in two stages utilizing a constant rate spring and damper for each stage. The first stage releases the reflector following initiation of two separation nuts, and a pin-puller initiates the second stage to deploy the reflector boom. The Aquarius reflector and boom deployment sequence is described in further detail in the Aquarius Commissioning Sub-section.

Connected to each of the antenna feed horns is an L-band radiometer to measure the microwave emission from the ocean with a center frequency of 1413 MHz. An L-band scatterometer shares the antenna with the radiometers to provide information to correct for the ocean surface roughness and transmits in the 1260MHz protected frequency. The radiometers (H, V, and ±45°) and scatterometer (co-polarization and cross-polarization) are polarimetric for correcting for Faraday rotation of the signals.

The Aquarius instrument has a solid, offset parabolic reflector antenna with three beams to scan the ocean surface spanning a combined 390 km total swath width. The mission orbit finishes a global-repeat cycle every seven days.

Highly accurate sea surface salinity retrievals from Aquarius instrument measurements are achieved via three primary methods: Averaging co-located data sets, performing on-orbit calibrations, and maintaining thermal stability of the key instrument subsystems to 0.1 K. Data averaging will be a ground processing activity and will include a time-range of averaging events. Initially, collected data will undergo 6 second averaging, for example. Over a 4 week period, the 7 day repeat cycle will have yielded at least 4 co-located samples of each Aquarius 6 second footprint and these will be averaged as well.

The absolute calibration bias will be corrected by applying data collected during on-orbit calibrations (such as during the Cold Sky Calibration maneuver) to adjust the coefficients of the retrieval algorithm.

Thermal stability is achieved by employing four Active Thermal Control (ATC) regions, one for each of the Ortho Mode Transducer assembly/Radiometer Front End radiators and one for the Radiometer Back End /Scatterometer radiator. Each zone is independently controlled by Proportional Integral Derivative software.

3.2.2.2 Microwave Radiometer (MWR)

The MWR measures the surface brightness temperature in the frequency range sensitive to geophysical parameters over the ocean to contribute to climate and hydrological forecasting. Primary MWR products are water vapor data, sea surface wind speed, rain rate data, cloud liquid water data and sea ice concentration. The MWR measurements should complement or enhance the accuracy of the Aquarius instrument.

The MWR consists of two radiometers: one at 23.8 GHz (K band) and the other, a polarimetric one, at 36.5 GHz (Ka band).

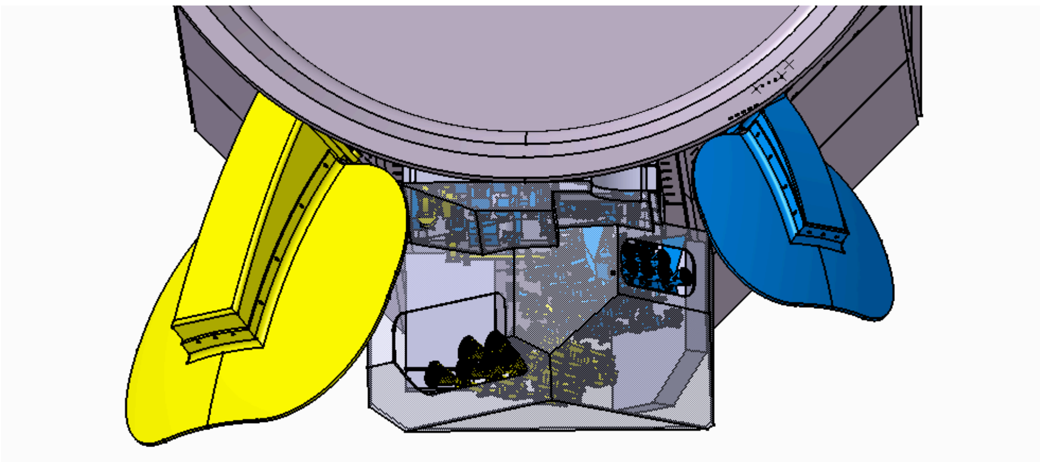


Figure 3-17 MWR final configuration on S/P

Each radiometer consist of an antenna (a reflector and eight feed horns arranged in pushbroom configuration) providing a swath width of about 380 km, a resolution of approximately 47 km and a sensitivity of 0.5 K, pointing the footprints at the same swath as the Aquarius instrument at incidence angles between 52º - 58º and viewing toward the night side of the orbit to avoid unwanted effects of solar reflections.

The 36.5 GHz radiometer receiver has two reception channels for the two polarizations H and V. The 23.8 GHz consist of one simple receiver that acquires the V polarization.

The MWR is supported by a dedicated fixed structural subsystem with no mobile parts. Mechanically, it consists of 3 main parts: one box that supports the two microwave receivers, the antennae feed horns, the MWR Power Distribution Unit and the MWR Thermal Control subsystem; one reflector of the 23.8 GHz antenna and one reflector of the 36.5 GHz antenna.

3.2.2.3 New InfraRed Sensor Technology (NIRST)

The NIRST main objective is the measuring of fire radiance with an adequate accuracy and resolution that guarantees the knowledge of fire characteristics such as temperature and released energy. Additional objective is the measure of Sea Surface Temperature (SST) over selected targets in order to support Aquarius Instrument corrections.

NIRST is an infrared push-broom scanner based on a couple of linear microbolometric arrays sensitive to Mid-Wave Infra-Red (MWIR) and Long-Wave Infra-Red (LWIR) spectral bands respectively.

Both sensors will scan simultaneously the same ground area with MWIR and LWIR bands in order to measure fire characteristics (in the thermal range 300-700 K). In addition, the LWIR array will detect waves in two different spectral bands centered at 10.85 and 11.85 microns respectively to allow SST measurements (in the thermal range 250-500 K).

The NIRST swath width is 180 Km with an on ground pixel of 350 m (pointing to nadir). In order to widen its scanning possibilities NIRST have an internal steering capability of +/- 30 deg, providing an equivalent swath-width of 940 Km (this internal steering capability will not affect the observatory performances).

3.2.2.4 High Sensitivity Camera (HSC)

The HSC instrument scientific objective is to improve the knowledge related with fire distribution, volcanic eruptions and lightning storms. The camera can be also used in the study of urban light intensities and polar auroras.

The HSC instrument will operate in real time mode over Argentina and in stored mode over other targets around the world (up to 180 passes per year).

The High Sensitivity Camera (HSC) is an instrument based on Time Delay Integration (TDI) Charge Coupled Device (CCD) technology. The HSC instrument points to nadir and measures the top of atmosphere radiance in the visible range of the spectrum (450-610 nm). Data collection is performed over the dark side of the sun terminator to avoid sensor saturation due to sun light reflection and atmospheric scattering effects.

The HSC has two components: the Electro Optical Component (HSCO) and the Electronics Component (HSCE). The HSCO contains two cameras with independent optical systems associated with their respective TDI CCD and spectral filters. Each optical system has a Field Of View (FOV) of 36.8 degrees and the angle between the optical axes of each system is 35 degrees. The total resulting FOV is 71.8 degrees with a small overlap of 1.82 degrees in the center. The center of the total FOV is pointing to nadir and the ground pixel size is 200 meters.

The HSCE provides: timing and control signals to the HSCO, receives commands from the S/P, transmits science data and housekeeping data to the S/P and has data storage capability (96 Mbytes) for science data.

3.2.2.5 Data Collection System (DCS)

The DCS instrument onboard the Observatory has the capability to receive and store environmental data transmitted by Data Collection Platforms (DCP) located on the ground (or near the ground) and equipped with environmental sensors. DCS will be used as a monitoring system to follow up the evolution of emergencies and natural or anthropogenic disasters and to:

- Satisfy demands of superficial and underground aquifer management (height of freatic water sources, contamination, salinity, etc).
- Acquire parameters of interest in agriculture (rains, floor humidity).
- Detect the presence of pollutants in the low atmosphere.

The DCP has characteristics of reliability, low power consumption and low maintenance, which make them ideal to be placed in inhospitable and difficult access areas. The system will be able to manage at least 200 platforms in the Argentine territory and will be compatible with Brazilian DCS.

The DCP transmitting frequency is 401.55 MHz (UHF). They transmit the information asynchronously without knowledge of the satellite position or accurate time. The DCS receiver tries to recover the information and, if successful, store it on board. The recovered data is then downloaded to the ground station for pre-processing and further distribution to the users.

The DCS instrument is composed by the Receiver and Signal Processing Unit, the UHF receiving antenna, harness and the structural fittings set. The total mass is 6 Kg.

3.2.2.6 Radio Occultation Sounder for Atmosphere (ROSA)

The ROSA instrument is provided by the Italian Space Agency (ASI) and consists of an integrated GPS receiver for scientific space applications in the field of atmospheric sounding by radio occultation of GPS signals.

Figure 3-18 ROSA GPS Receiver

The instrument main feature is to collect accurate pseudo-range and integrated Doppler measurements (raw data) at both L1 (1575 MHz) and L2 (1226 MHz) GPS frequencies. The GPS signals are acquired through three antennae: a navigation antenna pointing to the local orbital zenith and two sounding antennae (Radio Occultation Antennae), pointed toward the velocity and anti-velocity satellite vectors respectively.

The raw data collected by the zenith antenna is used for real time navigation purposes and for on ground precise orbit determination.

Figure 3-19 ROSA Zenith Antenna

The Radio Occultation Antennae provide raw data when the acquired GPS satellites are in conditions of near-occultation by the Earth limb, i.e. when the GPS signal passes through the Earth troposphere and ionosphere before reaching the antennae. The data is stored on board and, later on, transmitted to the ground for processing and application in atmospheric research.

Figure 3-20 ROSA Radio Occultation Antennae

The Radio Occultation Antennae are in a stowed position during launch configuration and will be deployed shortly after spacecraft separation.

3.2.2.7 CARacterisation et Modelisation de l'ENvironnement (CARMEN)

CARMEN payload is provided by the French Space Agency (CNES) and it is composed by the ICARE instrument and three SODAD detectors.

The main part of ICARE is the SPECTRE module that is intended to measure the radiation flux in the space environment. It is composed of three independent measurement channels made up of solid-state silicon detectors that are sensitive to various particles (electrons, protons, heavy ions). The instrument outputs are energy level spectrums with programmable integration times and periods and high rate event counters.

ICARE includes also an independent subsystem dedicated to the study of the radiation effects on various electronics components. This subsystem is called EXPERIENCE module.

The main function of the SODAD equipment is to detect micrometeoroids and orbital debris in the space environment. Each SODAD instrument is composed of a data acquisition unit, a CPU unit and a power unit with a segregated and dedicated card to the high voltage of the four MOS sensors.

The total mass of CARMEN is 6 Kg.

3.2.2.8 Technological Demonstration Package (TDP)

TDP is a prototype of a combined Inertial Reference Unit (IRU) to measure the spacecraft tri-axial inertial angular rate and Global Positioning System Receiver (GPSR) to provide spacecraft position, velocity and time. The objective of TDP is to demonstrate in-flight performance of both sensors and to provide baseline sensors for future CONAE missions.

The TDP instrument consists of three main boxes:

- Fiber Optics Package (FOP)
- TDP Electronic Box (GEB).
- GPSR antenna support and antenna.

The FOP package is a set of passive optical components as fiber optic sensing coils (one per each sensible axis). The sensing coils are placed on tetragonal structure faces where the optical axis of each coil is normal to those faces.

The GEB Box has eight modules:

- Four Gyro Electronics Modules
- One Single Board Computer module based in DSP21020

- One Single Board Computer module based in ERC32
- One GPSR module
- One DC/DC converter module

The DSP21020 is the main processing module for the inertial reference unit. The ERC32 is the main processing and communication module for the TDP. This module includes the GPS receiver and the 1553 communication interface to the S/P.

3.3 Ground Segment

3.3.1 Ground Stations

The ground stations selected to support the Aquarius/SAC-D mission are ETC (Córdoba; Argentina), the NASA Ground Network (NEN) and two ASI ground stations. The whole network comprises the following 6 tracking stations:

Station	Latitude (deg, N)	Longitude (deg, E)	Altitude (m)	Comments
ETC	-31.5241	295.5364	730	CONAE Córdoba; Argentina
ASF	64.8588	212.1418	205	NEN – ASF; Alaska
MGS	-77.8391	166.6671	153	NEN – McMurdo; Antarctica
SGS	78.2307	15.3897	497	NEN – Svalbard; Norway
WGS	37.9249	284.5234	-20	NEN – Wallops, USA
MAT	40.650	16.704	543	ASI – Matera; Italy
MAL	-2.996	40.195	12	ASI – Malindi; Kenia

Table 3-3 Ground Network

3.3.2 Ground Station Support

During normal operations the Observatory will be supported only by ETC (Commanding, HK telemetry and Science Data downlinks) and Matera (Science Data downlinks).

The NEN tracking stations (ASF, MGS, SGS and WGS) will be used during launch, monthly orbit maintenance maneuvers, in support of the Cold Sky Calibration and in the event of contingencies. The Aquarius Ground System manages the requirements for the NEN.

Malindi will support launch and orbit adjustment maneuvers.

Station		Use	

	Frequency		Operations
ETC (CONAE)	RX, TX S-Band RX X-Band	Primary Station TT&C and Science Data	Early Orbits and Commissioning, Science Operations Orbit maneuvers, Cold Sky Calibrations, Contingencies.
ASF (NEN)	RX, TX S-Band	TT&C Support	Launch, Early Orbits and Commissioning, Orbit maneuvers, Cold Sky Calibrations, Contingencies.
MGS (NEN)			
SGS (NEN)			
WGS (NEN)			
MAT (ASI)	RX X-Band	Science Data	Commissioning, Science Operations
MAL (ASI)	RX S-Band	HK Telemetry	Launch, Orbit maneuvers

Table 3-4 Ground Station Capabilities

3.3.3 CONAE Ground Segment

The CONAE Ground Segment (CGS) consists of CONAE Ground Station Facilities & Services that provides the following functionality:

- Observatory operations and control
- S/P data processing and storage
- Telemetry and stored data recovery and processing
- Science raw data storage and distribution
- SAC-D science data processing and distribution
- Orbit Determination and Maneuvering

Figure 3-21 shows the top level design concept of the CGS. This is a functional diagram of considerable level of abstraction and do not represent the actual architecture of the CGS.

The purpose of the functional diagram is to present the main functional components of the CGS and those of CONAE's foreign partners. In the figure, these components are represented by boxes.

The blue boxes represent CONAE's components. The green boxes represent all foreign components. The components depicted over the green background are located on foreign facilities. The components located over the blue background are located on CONAE facilities.

The box representing the flight segments is depicted in both colors due to the typical cooperative ownership of these segments. The box representing the users is located over the division between the green and the blue backgrounds and depicted in both colors, to represent that the users can be located on both countries and that the users might use simultaneously both CONAE and foreign instruments.

This diagram allows us to clearly identify the main interfaces between the components of the CGS and those of the Foreign Ground Segment. These interfaces are depicted with arrows.

The CODS Service (CONAE Orbit Dynamics Service) has a blue dotted border meaning that all ground segment components might interface with it (both the foreign and CONAE components).

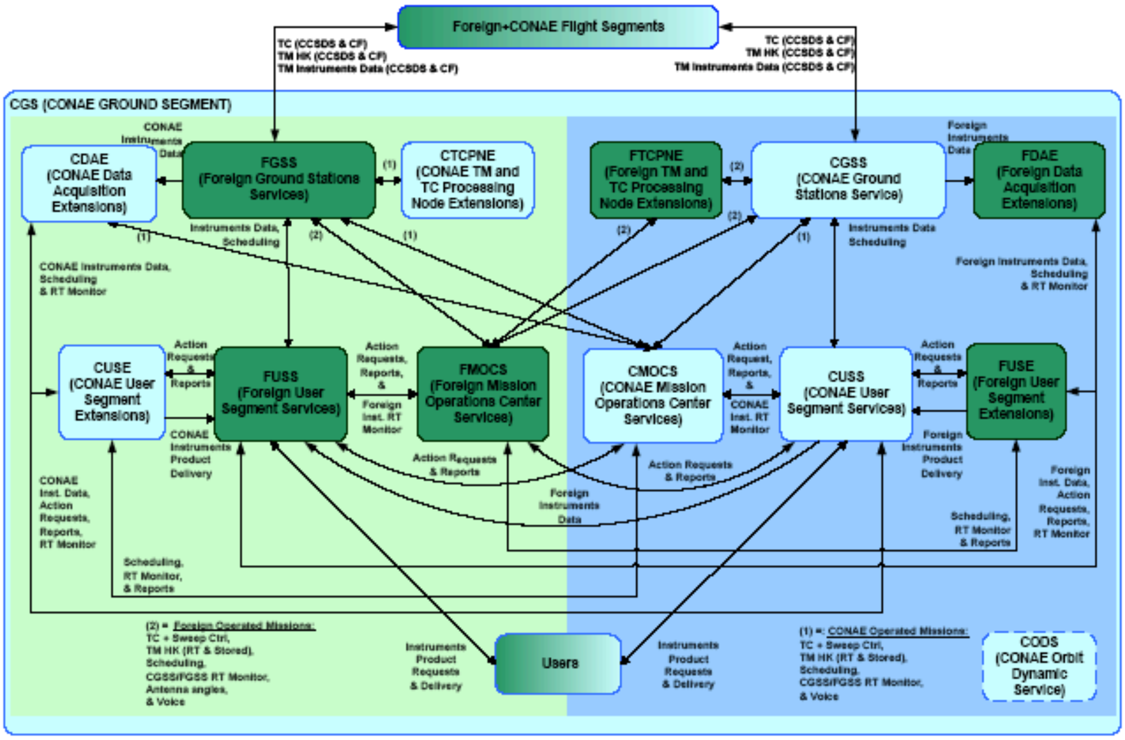


Figure 3-21 CGS Design Concept

We briefly describe all CONAE's ground segment components:

- The CGSS is CONAE Ground Stations Service. This service includes all CONAE's stations, ETC and any future station. Basically it consists of all CONAE's antennas, its accompanying RF equipment, Data Acquisition equipment, and its Monitor and Control systems.
- The CMOCS is CONAE Mission Operations Center Services. This service includes the Mission Operations Center of each one of CONAE's space missions (e.g. SAC-C's MOC, SAC-D's MOC, SAOCOM-1's MOC, etc.).

- The CUSS is CONAE User Segment Services. This are the services for both argentine and foreign users interested in products generated by CONAE, independently of being they products from its own instruments or not. This includes DISPA and the generation of each one of CONAE's instruments products at ETC.

- The CTCPNE are CONAE TM and TC Processing Node Extensions. This allows CONAE to receive TM and to send TC in a foreign location from and to CONAE's missions. This equipment is only necessary when the facilities at the FGSS do not support the TM and TC formats of CONAE's missions, e.g. CONAE equipment at INPE's facilities at Alcantara, Brazil, for the SAC-C mission.

- The CDAE are CONAE Data Acquisition Extensions. This allows a foreign partner to acquire some of CONAE's instruments data at a foreign location using the FGSS.

- The CUGSE are CONAE User Ground Segment Extensions. This allows a foreign partner to generate some of CONAE's instruments products at a foreign location. It is necessary to use the CDAE to acquire first CONAE instruments data. This is directly done in the foreign location, without acquiring or generating these products at CONAE location and transporting them to the foreign one.

- The CONAE Orbit Dynamic Services (CODS) include orbit determination, orbit propagation, TLE generation and distribution, ground station contacts generation, maneuver computation, etc. for both argentine and foreign, services and users.

The foreign ground segment components are:

- The FGSS is the Foreign Ground Stations Service. It parallels CONAE's CGSS representing all foreign stations (e.g. NASA's NEN, ASI's, etc.).

- FMOCS is the Foreign Mission Operations Center Services. It parallels CONAE's CMOCS representing all foreign Mission Operations Centers.

- FUGSS is the Foreign User Ground Segment Services. This parallels the CUGSS representing all user's services about products generated by a CONAE's foreign partners. In the case of the SAC-D mission it represents the Aquarius's user ground segment.

- The FTCPNE are the Foreign TM and TC Processing Node Extensions. This parallels CONAE's CCTCPNE allowing foreign partners to receive TM and send TC to their missions.

- The FDAE are the Foreign Data Acquisition Extensions. This parallels CONAE's CDAE allowing CONAE to acquire data from foreign partner missions, e.g. the DA equipment to acquire Radarsat data or the Italian DA equipment that is used to acquire COSMO-SkyMed data.

- The FUGSE are the Foreign User Ground Segment Extensions. This parallels CONAE's CUGSE allowing CONAE to generate some of the foreign partner's instruments products at CONAE locations. This is directly done in CONAE locations, without generating these products in the FUGSS and transporting them to the CUGSS.

3.3.4 SAC-D MOC

This section briefly describes the SAC-D MOC (Mission Operations Control). We focus now on the CMOCS, in this scenario CMOCS represents the SAC-D MOC, and in what follows we ignore all the components of the CMOCS that are not directly related with it. This is represented with colors in Figure 3-22. We keep the colors of Figure 3-21, for all those components that we keep considering, with red we highlight the SAC-D MOC on which we focus now, and in gray we depict all the components are link that we ignore. This system gives support for payload teams upload his commands and take care of the SAC-D platform services.

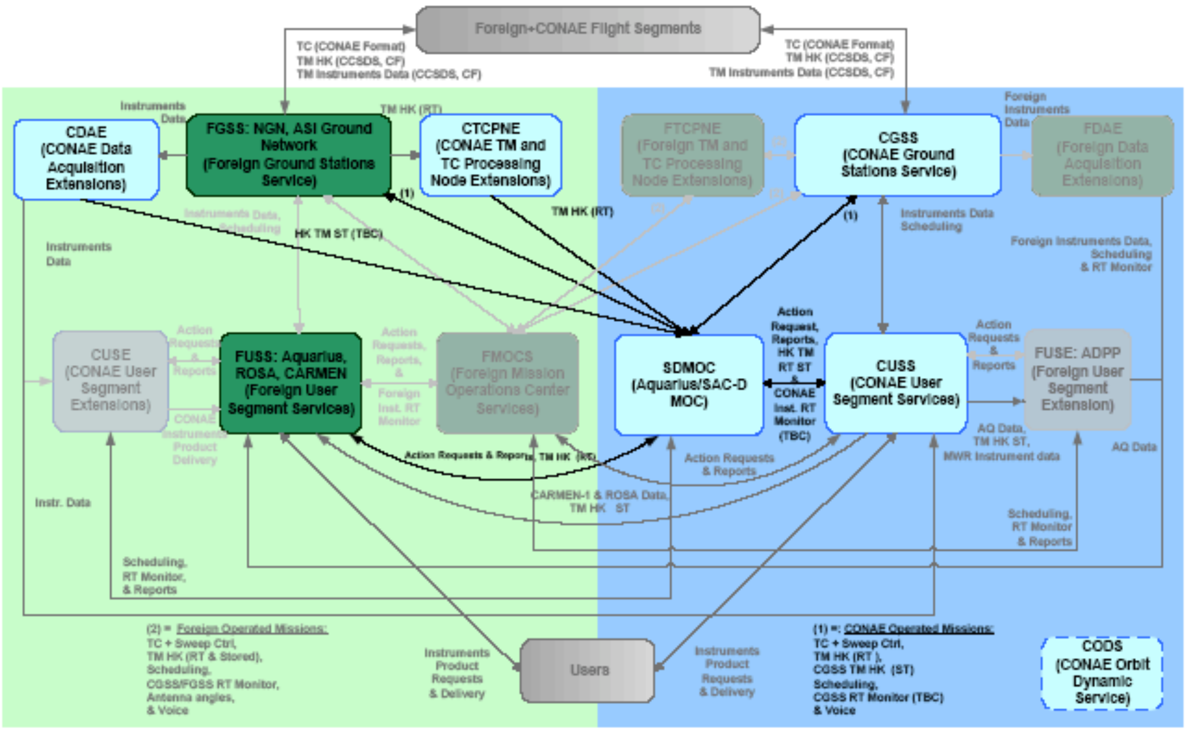


Figure 3-22 SAC-D MOC

Figure 3 shows the top level design concept of the SAC-D MOC. This is a functional diagram of considerable level of abstraction and do not represent the actual architecture of the SAC-D MOC. The purpose of this functional diagram is to present the main components of the SAC-D MOC. In the figure, these components are represented by the dark blue boxes. As before, the blue boxes (dark and light) represent CONAE's components and the green boxes represent all foreign components.

The diagram not only allows us to clearly identify the main interfaces between the SAC-D MOC and the other components of the CGS and the Foreign Ground Segment with more detail, but also, it shows the internal functional components of the SAC-D MOC.

As we said before, the diagram below is a functional diagram. In these functional diagrams we abstract all repeated instances of subsystems that have the same functionality. Avoiding this unnecessary repetition of instances and interfaces allows us to simplify these diagrams enhancing the understanding of the various functions of the subsystems in them. To help the reader matching these diagrams with the architectural ones, that match the reality, we have drawn a green dotted line enclosing the subsystems of the CGSS that in the actual architectural diagrams might appear more than one time repeated. Indeed, these subsystems appear one time for each one of CONAE's stations, i.e. each group of antennas in a definite location.

The NET and PE subsystems are crossed by the green dotted line meaning that those subsystems appear not only associated to each one of these groups of antennas, but also in the central position where the GSOC is located.

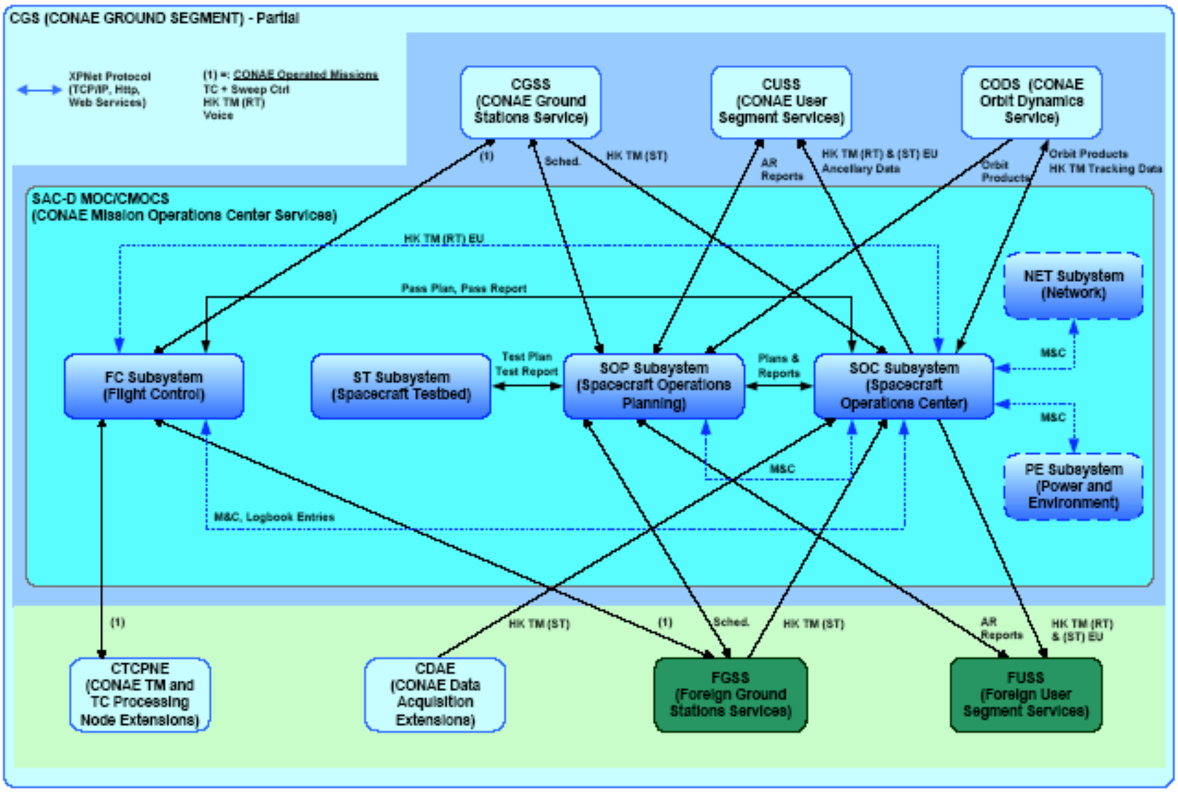


Figure 3-23 SAC-D MOC Design Concept Diagram

We briefly describe all the SAC-D MOC components:

- The FC (Flight Control) Subsystem. This subsystem is in charge of encapsulating Command into TC frames, upload TC frames, verification of satellite commands reception, implement retry technique, receiving TM, TM distribution, decoding TM, temporally storing and real-time TM visualization.

- The SOC (Stations Operations Center) Subsystem. This subsystem is in charge of managing the historical HK TM and units TM, it is the responsible of execute the plans and allow the analysis data.

- The SOP (Ground Stations Planning) Subsystem. This subsystem is in charge of managing the Action Request sent by the user and planning activities.

- The ST (spacecraft Testbed) Subsystem. This subsystem supports the development and tests of the Spacecraft Engineering and Flight Models. It contains units that handle the TM and TC of the Spacecraft both in RF and Baseband.

- The NET (Network) subsystem provides the connection between all subsystems and with other services. We avoid to depict this TCP/IP interfaces, signaling this with the spaced line of the box.

- The PE (Power and Environment) Subsystem. We avoid depicting the power interfaces, signaling this with the spaced line of the box.

3.3.5 Aquarius Ground System

The Aquarius Ground System is responsible for the Project's operations including coordinating with the Aquarius Science Team for planning, performing instrument monitoring, developing command requests for submission for instrument control, and science data processing. The Aquarius Ground System is also responsible for setting up the Project Service Level Agreement for the Mission support from the NASA Ground Network (NEN).

The Aquarius Ground System consists of three main segments (highlighted in blue in Figure 3-24): the Aquarius Command and Control System (ACCS), the Aquarius Data Processing System (ADPS), and the Physical Oceanography: Data Analysis and Archive Center (PO.DAAC).

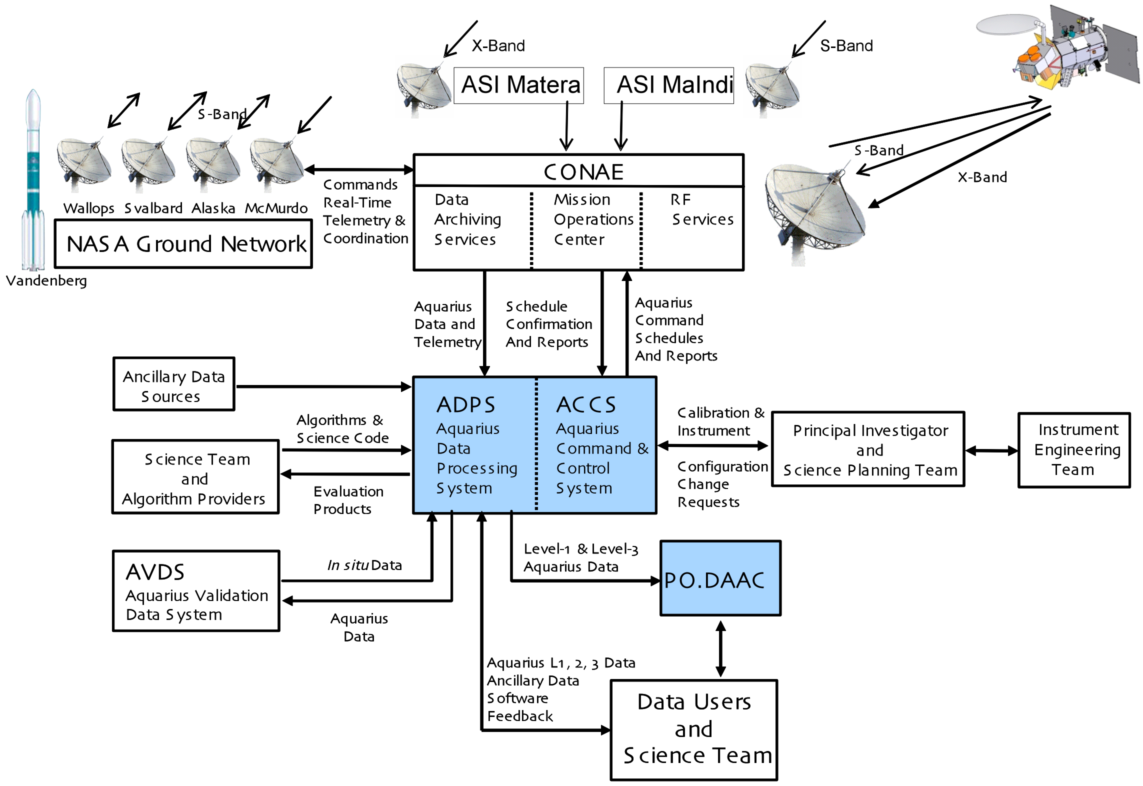


Figure 3-24 Aquarius Ground System and Interfaces

The Aquarius Ground System is integrated into the existing GSFC Oceans Data Processing System that processes science data for several operational ocean-viewing projects. The Aquarius Ground System's coordinates with the SAC-D Ground System's Mission Operations Control Center (MOC) for downlink data retrieval and providing Aquarius command requests for integration with the Mission Pass Plans or for real time transmission. The MOC will provide monitoring of key Aquarius instrument housekeeping telemetry during SAC-D ground station passes for real-time assessment of health and status.

The SAC-D Ground Systems provides coordination and establishes the interface between NEN and the CONAE Mission Operations Center (MOC). The Aquarius Ground System interfaces only through the CONAE MOC through ETC and cannot interface directly from the ground to Aquarius through the NEN. CONAE contracts for NEN use via the Aquarius Ground System as described in the Project Level Service Agreement (PSLA).

Aquarius instrument control function is through the Aquarius Command and Control Segment (ACCS) and provides instrument command requests via the CONAE-provided Command Scheduler and scripting tools. The ACCS also performs Aquarius instrument monitoring via the CONAE-provided Telemetry Viewer and associated graphing tools. Aquarius commands are scheduled separately by the ACCS in accordance with science requests and with ground station contact times provided by CONAE. The ACCS generated commands are then merged into the Observatory command pass plan by the Command Schedulers at the CONAE MOC.

The science data processing arm of the Aquarius Ground System, the Aquarius Data Processing System (ADPS) retrieves Aquarius science data files captured from the Observatory via the CONAE User Ground Segment Services (CUGSS). The ADPS then processes them to Level 3 science data products. The ADPS also archives and distributes files and products to both the JPL PO.DAAC and science users, including the Aquarius Science Team. To support data processing and data validation, the ADPS additionally retrieves and processes ancillary data and validation data from sources identified by the Aquarius Science Team.

The third segment of the Aquarius Ground System is the JPL PO.DAAC which archives level 1, 2, and 3 Aquarius data products and will distribute them to the scientific user community. The PO.DAAC is an existing JPL facility.

4.0 Launch Phase

The Launch Phase includes: Lift-off, ascent, fairing separation, automatic S/P turn-on sequences and Observatory separation from the L/V.

The Observatory, having a launch mass of 1675 Kg will be launched from Space Launch Complex 2 West (SLC-2W) at Vandenberg Air Force Base (VAFB) on a Boeing Delta II 7320-10. The boost-to-orbit trajectory is designed to place the Observatory into the desired orbit while meeting L/V structural, heating, controllability, and solid motor separation constraints.

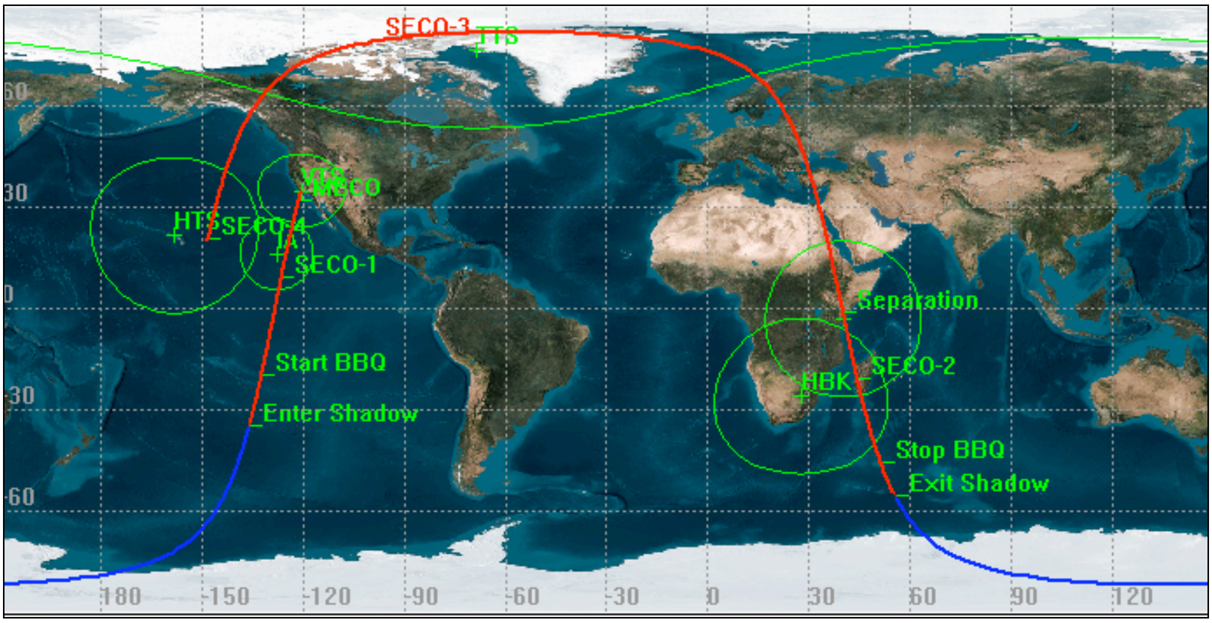


Figure 4-1 Delta-II Trajectory

4.1 Launch Opportunities

Aquarius/SAC-D launch opportunity starts on June 09, 2011 with a launch opportunity occurring every day, once per day. The daily launch opportunity shall correspond to achieving the 06:00 PM (±5 min) MLT at the first ascending node following separation.

4.2 Launch Window

The duration of the Aquarius/SAC-D Projects launch window shall be the duration required by the Delta II L/V to achieve the target Mean Local Time of the first Ascending Node (MLT-AN) target following Observatory separation to within ± 5 minutes, taking into account the L/V launch sequence timing and injection dispersions.

4.3 Nominal Trajectory

Once the RS-27A main engine thrust has reached the required level, the three GEM solid motors are ignited producing the L/V liftoff. The solid motors burn until approximately L+64 seconds but they are not jettisoned until L+99 seconds in order to satisfy range safety trajectory shaping constraints.

Main Engine Cut-Off (MECO) occurs at 264 seconds after liftoff when booster propellants are depleted. Stage I-II separation follows 8 seconds later with second stage ignition occurring at L+277 seconds.

The payload fairing separation event occurs when the free molecular heating rate is equal to or less than 1135 W/m^2 (this is a mission requirement) at an altitude of about 130 km. It is at this point the Observatory is open to the space environment.

From liftoff until fairing separation, the Observatory will remain in the OFF state. At payload fairing separation, the circuit crossing the Observatory-to-L/V umbilical interface will be broken. Opening this circuit will close the relays that allow the battery to power on the following S/P elements:

- Command and Data Handling electronics (C&DH)
- S-band transceiver - Receiver 1
- S-band transceiver - Receiver 2
- Remote Terminal Units
- AOCS Electronics
- Power Control Electronics (PCE)
- Battery Management Unit (BMU) + Voltage Regulator (VREG)
- Mass Memory
- Magnetometer
- Reaction Wheel Assembly (RWA): (0 rpm; no rotation)
- Torque Coils (no magnetic field generation)
- Gyros (internal laser)
- Propulsion Tank Pressure transducer

These elements will remain in stand-by configuration until the Observatory separation is detected. At the completion of the initialization task, the following activities will start:

- Housekeeping (HK) data collection and storage in mass memory
- Self test of the powered on equipment
- Supervision of the subsystems health status and insertion into the telemetry
- Battery charge control

The second stage burn continues until L+689.7 seconds. At second stage engine cutoff (SECO-1) the vehicle is in a 157 x 669 Km. transfer orbit.

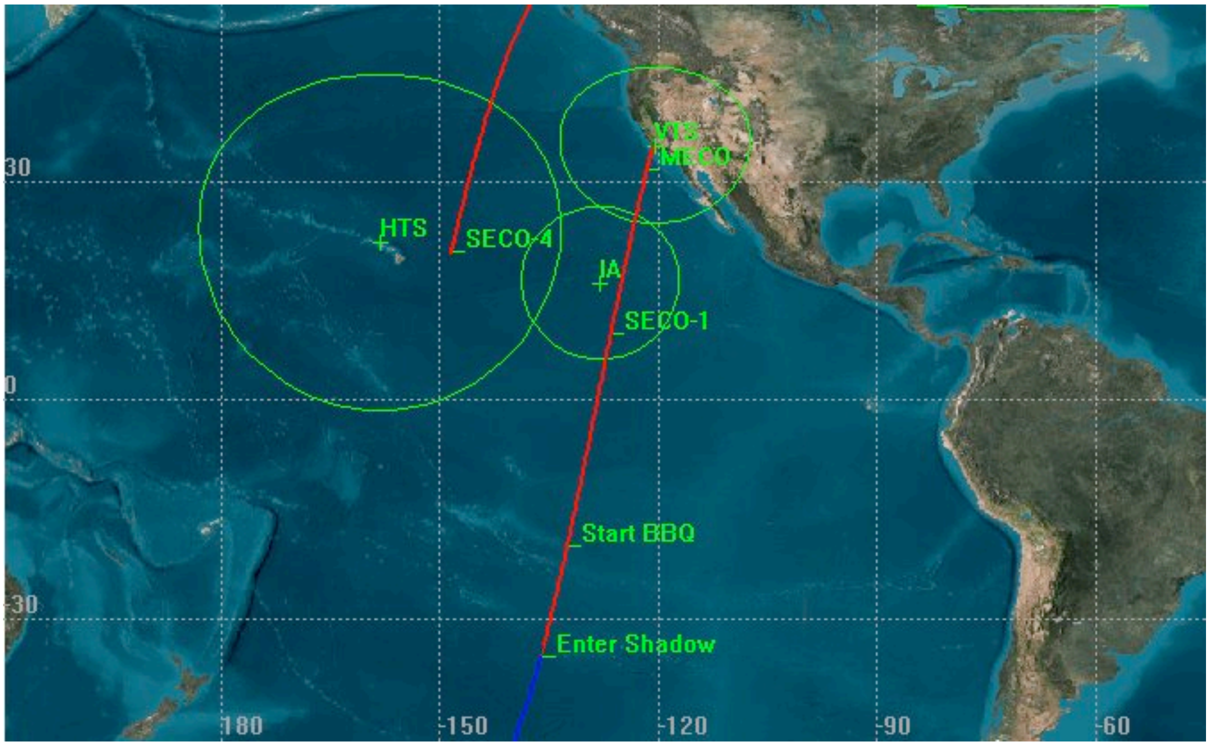


Figure 4-2 Launch

The second stage performs two sets of attitude reorientation maneuvers during the coast phase between SECO-1 and the first restart. The first maneuver positions the launch vehicle $+X_{LV}$ axis ($+Y_{SC}$) perpendicular to the sun. This is accomplished with a roll/pitch sequence. The L/V then performs a BBQ roll from L+1110 to L+2850 seconds, first at +1.5 and then at -1.5 degrees/second.

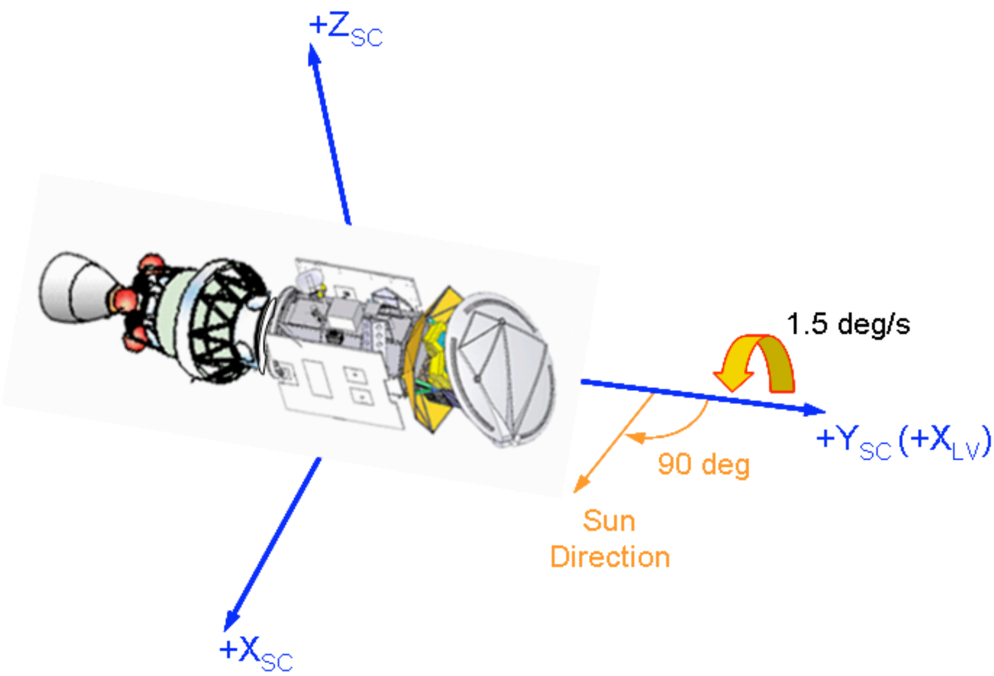


Figure 4-3 Barbeque Roll

The second maneuver points the second stage $+X_{LV}$ axis into the required spatial orientation for the restart burn as well as attaining a preferred roll orientation for telemetry coverage during the restart burn. This reorientation maneuver is accomplished with a roll/pitch/roll maneuver.

The second stage restart burn lasts 13 seconds and takes place in view of Hartebeesthoek (HBK) and Malindi (MAL) tracking stations.

4.4 Deployment Strategy

Following engine cutoff (SECO-2), the second stage performs a combined roll/pitch/roll maneuver to achieve the desired Observatory separation attitude, i.e. with the Observatory's $-Y_{SC}$ axis pointing towards the Sun and the $+Z_{SC}$ axis pointing Nadir.

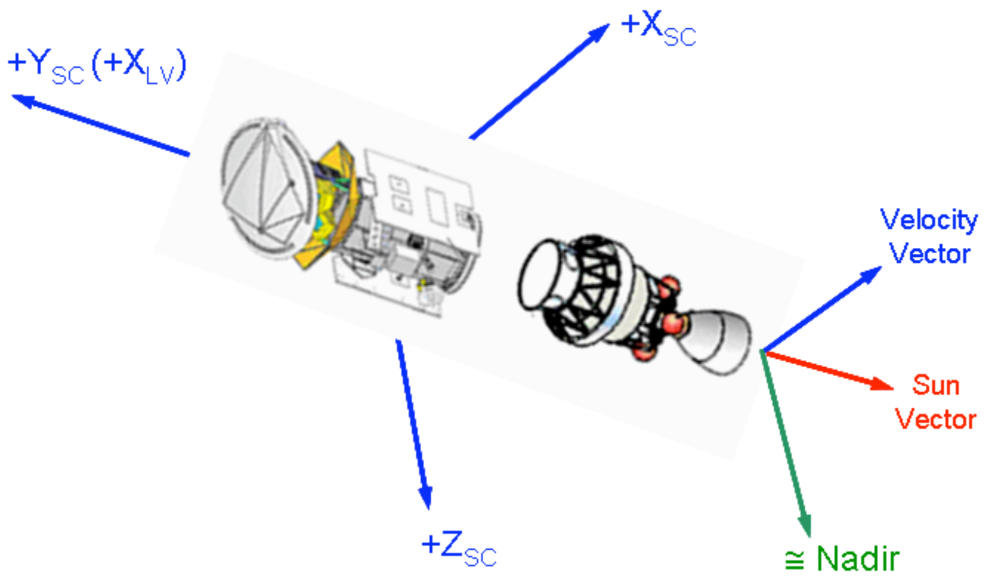


Figure 4-4 Separation Attitude

Five minutes after SECO-2, the second stage event controller activates the separation system. The clampband assembly that secured the Observatory is pyrotechnically released. Approximately 30 seconds after the clampband is released (damping period) the secondary latches are released and the second stage performs a back-away maneuver from the spacecraft.

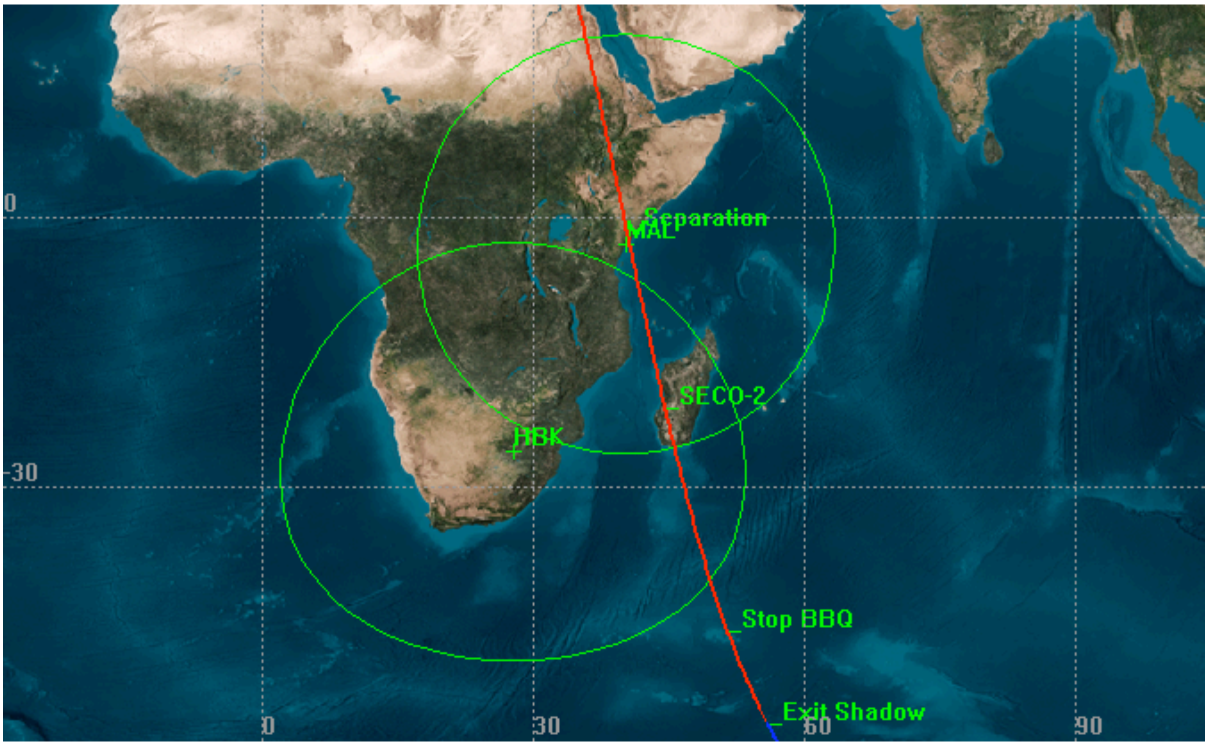


Figure 4-5 Separation

The Observatory is separated at 3585 seconds after liftoff in view of Malindi tracking station and reaches the first ascending node about 60 minutes after liftoff at which point the osculating orbit requirements are met.

After Observatory separation, the second stage will back away from the Observatory and perform a maneuver for collision avoidance and to establish a minimum impingement orientation with respect to the Observatory to minimize the impingement of contamination products generated from the second stage propellant depletion burn.

4.5 Timeline

Event	Time (sec)	Time (min)	FS (min)	UTC
Liftoff	0	0.0		14:19:41
Mach 1	36	0.6		14:20:17
Maximum Dynamic Pressure	50	0.8		14:20:31
Solid Motors Burnout	64	1.1		14:20:45
Jettison Solid Motor Casings	99	1.7		14:21:20
Main Engine Cutoff	264	4.4		14:24:05
Stage I-II Separation	272	4.5		14:24:13
Stage II Ignition	278	4.6		14:24:19
Jettison Fairing	296	4.9		14:24:37
Service Platform-ON	296	4.9	0.0	14:24:37

SECO-1	690	11.5	6.6	14:31:11
Begin Coast Phase	690	11.5	6.6	14:31:11
Start BBQ-Mode	1110	18.5	13.6	14:38:11
Enter Shadow	1218	20.3	15.4	14:39:59
Exit Shadow	2680	44.7	39.7	15:04:21
Stop BBQ-Mode	2850	47.5	42.6	15:07:11
Stage II Restart	3250	54.2	49.2	15:13:51
SECO-2	3263	54.4	49.4	15:14:04
Begin Stage II Steering Program	3315	55.3	50.3	15:14:56
End Stage II Steering Program	3535	58.9	54.0	15:18:36
Fire Separation Bolts	3556	59.3	54.3	15:18:57
Separate Observatory	3585	59.8	54.8	15:19:26

4.6 Second Stage Post-Separation Trajectory

Following spacecraft separation, the second stage utilizes its helium retro system for 41.5 seconds to back away from the spacecraft.

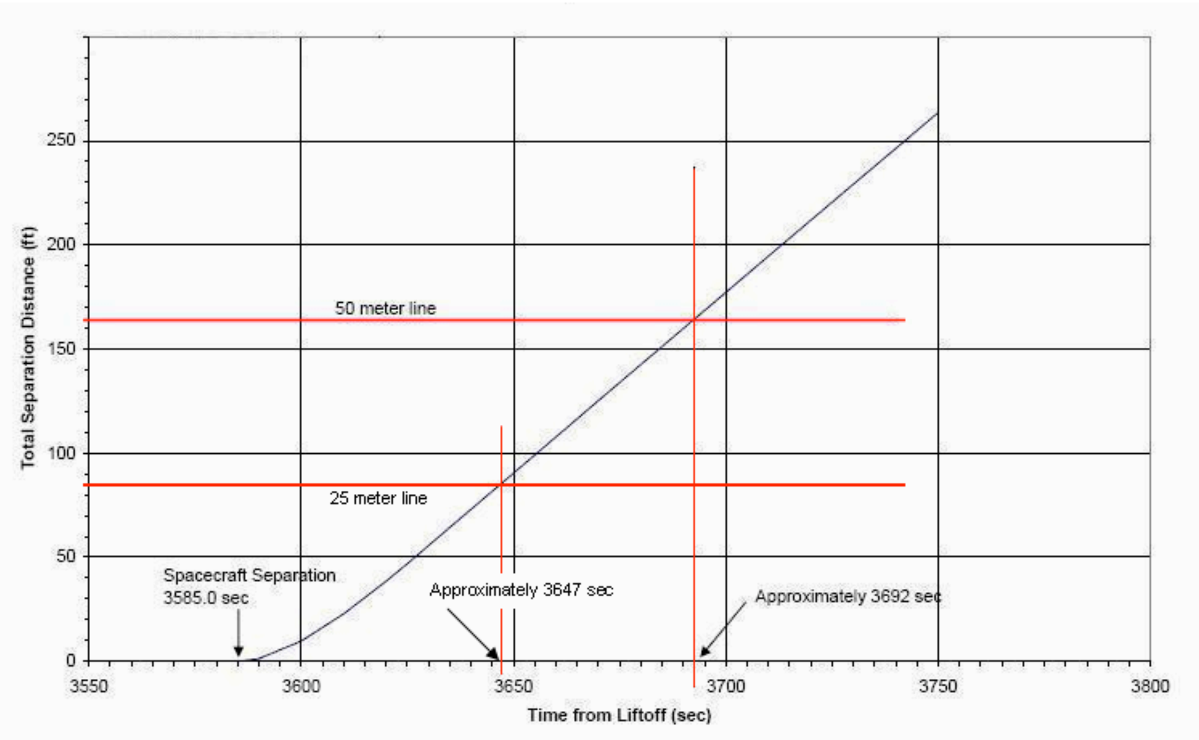


Figure 4-6 Separation distance between AQ/SAC-D and the L/V

Once the separation distance between the second stage and spacecraft is sufficient to ensure the spacecraft contamination constraint is not violated, the second stage performs a 5-second evasive restart burn over the Thule, Greenland tracking station. Approximately 16.6 minutes after the evasive restart burn, the second stage performs a final restart burn over the Hawaii tracking station to deplete its remaining propellant and minimize its explosive potential. This depletion burn nominally lowers the perigee altitude of the second stage orbit to 194 Km. to reduce its orbit lifetime.

5.0 Early Orbit and Observatory Commissioning Phase

The Early Orbit and Observatory Commissioning Phase begin at Observatory separation and perform S/P checkout, operational orbit acquisition and verification of the Observatory basic functions.

The S/P is designed to detect separation and to perform the following automatic actions:

- Attitude and Orbit Control Subsystem (AOCS) will initiate attitude control.
- Automatic S-Band transmitter power ON
- Solar Array Deployment

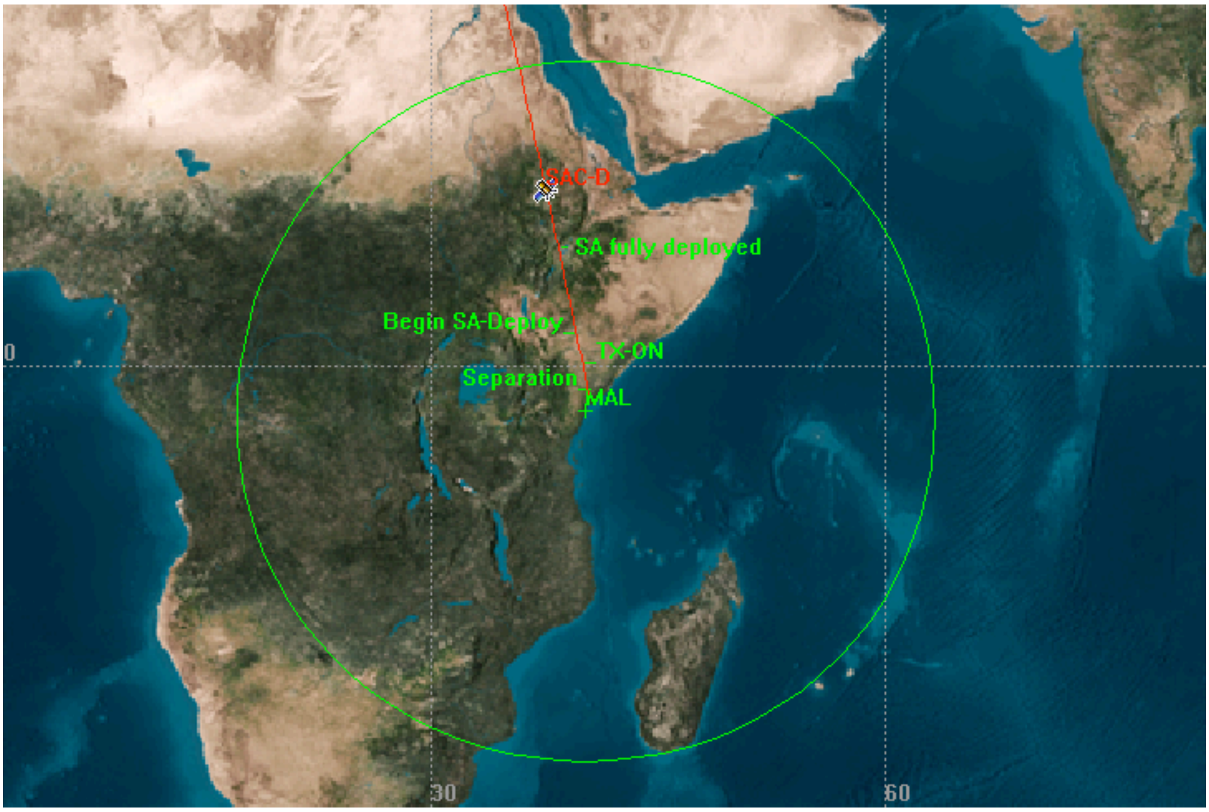


Figure 5-1 Early events after separation

The AOCS will automatically enter into Survival mode after separation, but it will switch to Safe Hold if it can determine where the z-axis is with respect to nadir.

The S-Band transmitter will be automatically turned ON 30 seconds after separation.

The solar array will be deployed 60 seconds after separation, when the distance between the Observatory and the L/V second stage is larger than 25 meters.

The S-Band transmitter will be automatically turned OFF 6 minutes after separation and will be automatically turned ON over the first pass over Svalbard (~15 minutes after separation). All subsequent S-Band transmitter turn-ON and OFF will be executed either by the use of time-tagged commands or Earth telecommands.

Event	Time (sec)	Time (min)	FS (min)	Sep (min)	UTC
Liftoff	0	0.0			14:19:41
Service Platform-ON	296	4.9	0.0		14:24:37
Separate Aquarius/SAC-D	3585	59.8	54.8	0.0	15:19:26
SAC-D S-Band TX-ON	3615	60.3	55.3	0.5	15:19:56
Malindi Acquisition Of Signal (AOS)	3620	60.3	55.4	0.6	15:20:01
Solar Array Deployment	3645	60.8	55.8	1.0	15:20:26
SAC-D S-Band TX-OFF	3938	65.6	60.7	5.9	15:25:19
Malindi Loss Of Signal (LOS)	3938	65.6	60.7	5.9	15:25:19
Svalbard AOS	4524	75.4	70.5	15.7	15:35:05
Alaska AOS	5132	85.5	80.6	25.8	15:45:13
Svalbard LOS	5278	88.0	83.0	28.2	15:47:39
Alaska LOS	5862	97.7	92.8	38.0	15:57:23
McMurdo AOS	7484	124.7	119.8	65.0	16:24:25
McMurdo LOS	8234	137.2	132.3	77.5	16:36:55
Svalbard AOS	10402	173.4	168.4	113.6	17:13:03
Alaska AOS	10947	182.5	177.5	122.7	17:22:08
Svalbard LOS	11118	185.3	180.4	125.6	17:24:59
Alaska LOS	11698	195.0	190.0	135.2	17:34:39
McMurdo AOS	13328	222.1	217.2	162.4	18:01:49
McMurdo LOS	14062	234.4	229.4	174.6	18:14:03
Svalbard AOS	16636	277.3	272.3	217.5	18:56:57
Alaska AOS	16758	279.3	274.4	219.6	18:58:59
Svalbard LOS	16970	282.8	277.9	223.1	19:02:31
Alaska LOS	17428	290.5	285.5	230.7	19:10:09
McMurdo AOS	19224	320.4	315.5	260.7	19:40:05
McMurdo LOS	19904	331.7	326.8	272.0	19:51:25
Svalbard AOS	22317	372.0	367.0	312.2	20:31:38
Alaska AOS	22540	375.7	370.7	315.9	20:35:21
Svalbard LOS	22843	380.7	375.8	321.0	20:40:24
Alaska LOS	23100	385.0	380.1	325.3	20:44:41
McMurdo AOS	25179	419.7	414.7	359.9	21:19:20
McMurdo LOS	25761	429.4	424.4	369.6	21:29:02

Córdoba AOS	26287	438.1	433.2	378.4	21:37:48
First X-Band Downlink	26613	443.6	438.6	383.8	21:43:14
Córdoba LOS	26939	449.0	444.1	389.2	21:48:40

Table 5-1 Events after separation

The ROSA Radio Occultation Antennae need to be deployed TBD minutes (/hours) after separation.

The first X-Band data downlink will be performed over ETC about 6.5 hours (4 orbits) after separation.

5.1 Timeline

The Early Orbit and Observatory Commissioning Phase last 45 days following launch. The nominal timeline is shown in Figure 5-2

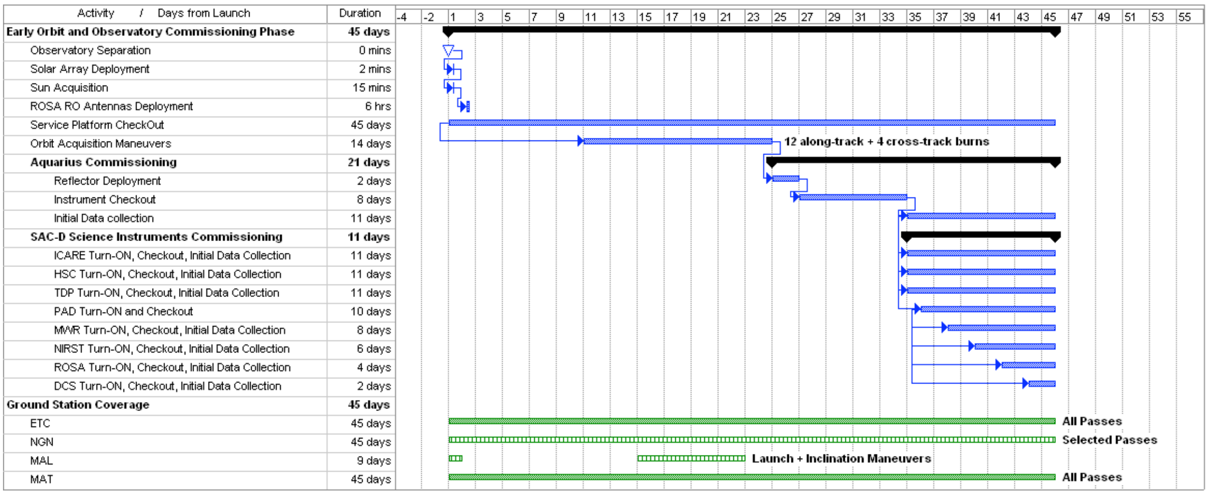


Figure 5-2 Commissioning timeline

5.2 Service Platform Checkout

During the early orbits, the real-time HKT is downloaded during each S-band ground station contact. Stored HKT is downloaded during each X-band ground station contact. This will permit, from S/P power ON, a complete verification of the performance of the telemetry downlink, the operation of the Mass Memory (MM) units, the power generation, the thermal control subsystem performance and the battery charge status.

Tests of the up and down links by means of end-to-end tests involving the main ground station and the support stations and the primary set of onboard transmitters and receivers are performed. Backup systems will not be tested until they are needed. All primary elements of the S/P will be assessed. This will include:

- Checkout of the three axis magnetometer and torque rods and verification that they are fully operational and meet performance specifications.
- Power ON of the Gyros and verification that they are fully operational and meet performance specifications.
- Checkout of the Bus-GPS to establish it is fully operational and meets performance specifications.

On the 10 days following launch C&DH and AOCS sensor and actuators operational modes will be fully tested.

Operational AOCS modes are: Safe-hold, Survival, Mission (Inertial and Yaw Steering), Cold Sky calibration and Propulsion. The first cold sky calibration will be performed 2 months after launch.

Operational performance and stability of each subsystem of the S/P will be completely verified.

5.3 Achieving the Operational Orbit

Following the S/P checkout the propulsion subsystem functional and performance tests will begin. Orbit Determination (OD) will be performed on a daily basis. Based on the OD results, a sequence of altitude and inclination maneuvers will be performed in order to remove L/V injection errors.

The design of the operational orbit acquisition strategy will be based on the propulsion system performance and current L/V injection errors. Time and duration of the burns shall take into account ground station visibility of the maneuvers. This sequence of maneuvers will place the Observatory into the operational orbit.

The acquisition sequence goals are assumed to be the following:

- Correct the orbit semi-major axis in order to achieve its nominal value,
- Correct the orbit inclination in order to achieve its nominal value.
- Correct the orbit eccentricity vector magnitude and orientation in order to attain frozen orbit conditions.

The orbital maneuvers needed to perform corrections to the semi-major axis and to the eccentricity (orbit altitude corrections) are along-track maneuvers. We can distinguish two different cases:

- If the initial orbit altitude is lower than nominal, the correction maneuvers are performed keeping the nominal Observatory attitude
- If the initial orbit altitude is higher than nominal, the Observatory attitude has to pitch 180°, keeping the $+X_{SC}$ axis toward the anti-velocity vector during the maneuver.

The orbital maneuvers needed to perform corrections to the inclination are cross-track maneuvers The Observatory attitude during these maneuver is to yaw 90° and point the $+X_{SC}$ toward the sun, the $+Z_{SC}$ toward nadir, and the $+Y_{SC}$ in the velocity or anti-velocity vector.

The optimal thruster firing for the orbit inclination maneuver would occur at the equator so there would be 90° yaw maneuver (~16 minutes) prior to equatorial crossing, a ~8 minute burn, and another 90° yaw maneuver (~16 minutes) to return to nominal attitude. SAC-D would likely perform this maneuver over Malindi, the Italian ground station.

A possible orbit acquisition sequence designed to correct the Delta II launcher 3σ injection errors is listed in Table 5-2:

Maneuver Type	Correction	Attitude	Days after Launch	Duration (min)
Along-track (2 burns)	Altitude	0° or 180° pitch	10	7 (×2)
Along-track (2 burns)	Altitude	0° or 180° pitch	11	7 (×2)
Cross-track (1 burn)	Inclination	±90° yaw	12	9
Along-track (2 burns)	Altitude	0° or 180° pitch	14	7 (×2)
Cross-track (1 burn)	Inclination	±90° yaw	15	9
Along-track (2 burns)	Altitude	0° or 180° pitch	17	7 (×2)
Cross-track (1 burn)	Inclination	±90° yaw	18	8
Along-track (2 burns)	Altitude	0° or 180° pitch	20	7 (×2)
Cross-track (1 burn)	Inclination	±90° yaw	22	7
Along-track (2 burns)	Altitude	0° or 180° pitch	24	7 (×2)

Table 5-2 Orbit Acquisition Sequence

5.4 Instrument commissioning

The Science Instruments Commissioning Phase starts 25 days after launch and assumes that the S/P has been fully checked out and the acquisition of the operational orbit was completed.

This phase includes instrument observations, science and instrument data collection, and instrument parameter adjustments that allow for science data and algorithm validation, and may last up to 21 days for complete instrument calibration and science data validation. Instrument data taken during this phase will be reprocessed to generate actual science data products following data validation.

5.4.1 Aquarius

5.4.1.1 Objectives of Aquarius Commissioning

Aquarius Commissioning is a sub-Phase of the SAC-D Early Orbit and Observatory Commissioning Phase. The Objective of the Aquarius Instrument Commissioning is to transition Aquarius from the post-Launch configuration with the survival heaters enabled to the Mission Mode of Operations and verify that the instrument is ready to begin Science Operations. The general activates associated with Aquarius commissioning include deploying the Aquarius reflector, incrementally power up and checkout all of its sub-systems, and finally initial data collection.

In addition to preparing Aquarius for science operations, this activity determines the health of the Aquarius instrument following the stress of launch and exposure to the space environment.

5.4.1.2 Commissioning Needs and Constraints

5.4.1.2.1 Ground Station Coverage

The relative timing of these sequenced Commissioning steps is often driven by the available ground station coverage. Since Aquarius is in a 7-day repeat cycle, the NASA Ground Network (NEN), ASI Matera, and Cordoba (ETC) ground station coverage is well known. All NEN stations (i.e., McMurdo, Wallops, Alaska, and Svalbard) will provide S-band coverage throughout the Aquarius Commissioning period. This provides ample coverage to retrieve housekeeping telemetry following each commissioning step to verify successful command execution and readiness to proceed to the next step.

The major Aquarius Commissioning steps include:

- powering up the instrument's master clock and ICDS,
- boom and antenna deployment,
- powering the Radiometer, turning on the Digital Processing Unit (DPU),
- powering the Scatterometer, and
- enabling the four zones of the ATC.

Each of these major activities will be successfully verified before proceeding to the next by monitoring the housekeeping data stream and/or the dedicated high rate science and that comes down the S-Band and X-Band downlinks over ETC and Matera. The Matera ground station can only receive the X-Band downlink and it will take several hours to transfer to the MOC the received data before being received by the Aquarius Ground System. The timing of the instrument check-out for steps that require ground verification need to either plan to utilize ETC or allow time for the data to be received at Matera and transferred to ETC. The Aquarius team will participate in commissioning activities from both the Aquarius and CONAE operations centers to be able to view and process real time and non-realtime data necessary to verify instrument health and performance.

5.4.1.2.2 Aquarius Commissioning Schedule

Aquarius Instrument Commissioning starts 25 days after launch and assumes that the S/P has been fully checked out. The Observatory should have achieved a frozen orbit consistent with the mission requirements (657±1.5 km altitude, 98 degree inclination, and a 06:00 PM ascending node).

Aquarius has been allocated 10 days to complete the instrument deployment and checkout phase prior to beginning Initial Data Collection. One week's worth of activities has been identified, with the remaining 3 days reserved as margin. If those three days are not needed, then the initial Aquarius data collection period begins early. Figure 5-3 shows the sequence of Aquarius commissioning events along with available ground station coverage.

If anomalies occur during S/P checkout or during orbit maintenance maneuvers, Aquarius instrument's initial turn-on, deployments and commissioning can be delayed for up to 6 months with the stipulation that its survival heaters are enabled.

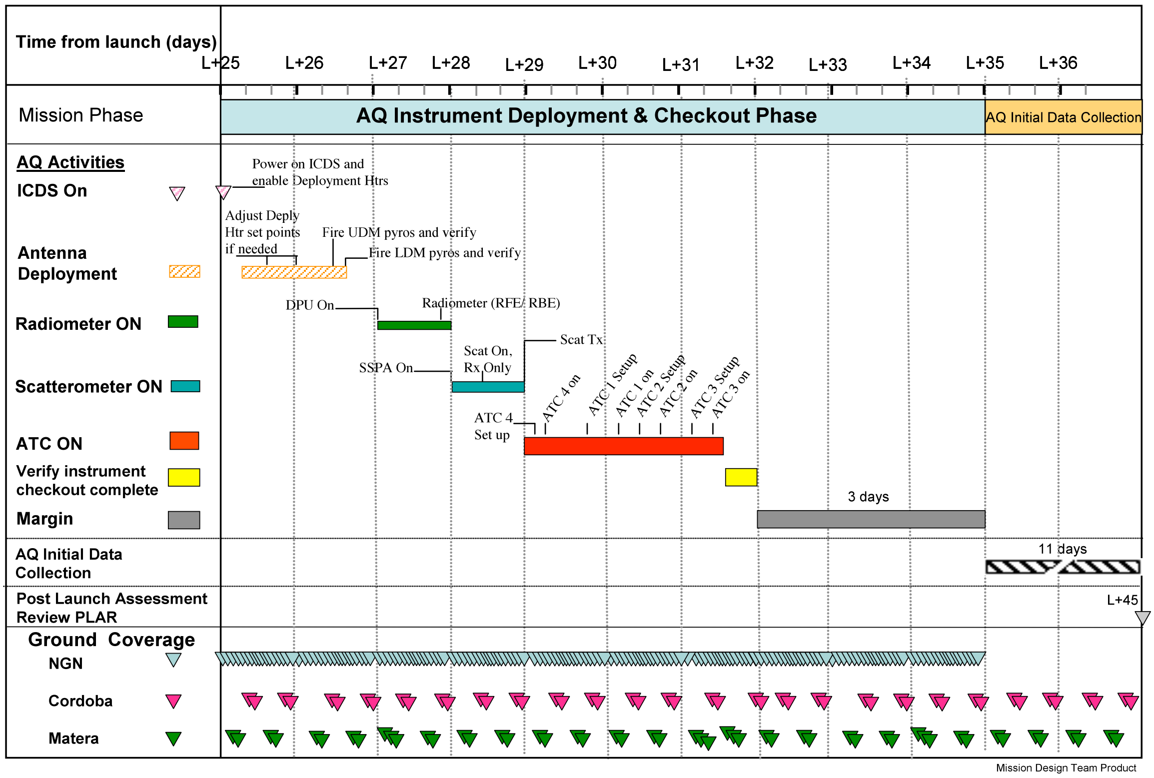


Figure 5-3 Aquarius Instrument Commissioning Timeline

5.4.1.2.3 Mode Changes

Aquarius begins the Commissioning sub-Phase in the stowed configuration, and in the OFF with Survival mode. Aquarius has remained in this state since Launch fairing separation. At the start of the Aquarius Commissioning sub-phase, the instrument will be put into Standby mode for ICDS checkout and for antenna deployment.

Following deployment, the rest of the instrument subsystems will be incrementally turned on until the Instrument mission mode is achieved (i.e., tight thermal control established, scatterometer transmitting, and instrument collecting science data).

Aquarius maintains Standby Mode during the deployment. The S/P uses Mission Mode prior to and following Aquarius deployment. During the deployment, the S/P will be in Safe Hold Mode, a sub-mode of mission Mode that does not implement the LVLH to prevent the possibility of reacting aversely to torques during deployment.

This ensures there is no interference between the attitude control subsystem and the deployment actuation.

5.4.1.3 Aquarius Commissioning Description

Aquarius Instrument commissioning begins with the ICDS turn-on, followed by antenna deployment. Once deployment activities complete successfully, the Aquarius instrument components are incrementally turned on and checked for functionality. The turn-on sequence involves powering the Radiometer, Scatterometer, and the ATC separately and assessing their operational health. Roughly one day will be spent on checking out each of these subsystems.

5.4.1.3.1 L+Day 25: ICDS

The first day of the Aquarius instrument commissioning is dedicated to preparing for the Aquarius reflector and boom deployment. The commissioning activities start with the turn-on of power to the instrument master reference clock and the ICDS. These pre-deployment steps place the instrument in Standby mode. With the ICDS operational, the ground can ascertain the instrument health and readiness to proceed with deployment. The ICDS also provides autonomous deployment heater control to ensure that the mechanisms are within their operational range. If necessary, the set-points for these software-controlled deployment heaters can be changed by ground command. It's anticipated that 4 orbits (6.7 hrs) are required to stabilize the mechanism temperatures. The baseline plan allows the commissioning team an opportunity at the end of Day 1 and another at the start of Day 2 to adjust the deployment heater set-points, if necessary.

5.4.1.3.2 L+Day 26: Aquarius Deployments

Once it has been verified on Day 2 that both deployment mechanism temperatures are stable and that the S/P is in Safe Hold mode, the deployment commands will be sent. The Aquarius reflector is held in the launch configuration by two restraints on the reflector and one on the boom. The Aquarius reflector deployment is a two stage event that first releases the reflector and then deploys the boom (see Figure 5-4).

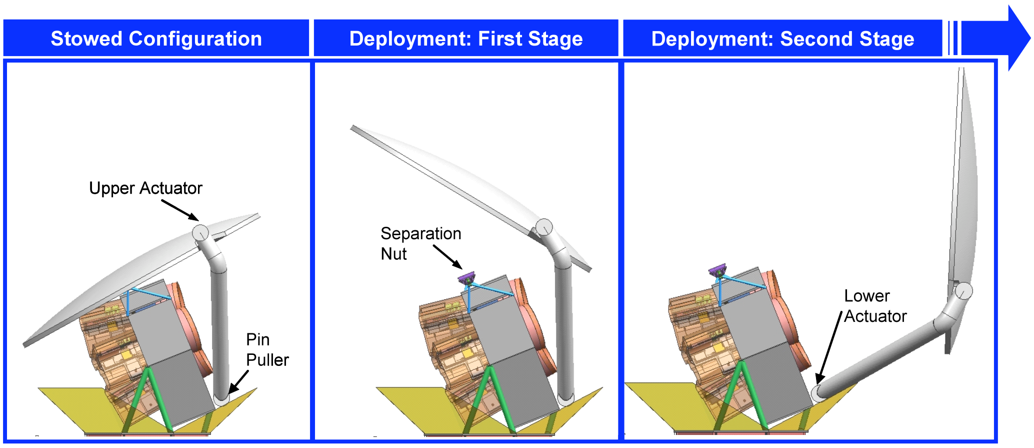


Figure 5-4 Aquarius Reflector and Boom Deployment

The first event involves simultaneously initiating two separation nuts to release the reflector. The reflector release is supported by a pair of push-off springs that help the reflector move in the correct direction. Once released, the Upper Deployment Mechanism rotates and latches the reflector to complete the first stage deployment. A limit switch provides the appropriate housekeeping telemetry that the reflector is stowed and a redundant pair of switches will indicate that the reflector is latched in the deployed state. The temperature sensors on the reflector should also provide an indication that deployment or the orientation of the reflector changed. Each deployment event travels 60 degrees and are expected to take between 10 to 60 seconds depending on mechanism damper temperatures.

The baseline communication strategy is to schedule overlapping NEN passes during each deployment event to provide maximum real-time commanding and telemetry. Once it has been verified that the reflector successfully deployed and that the mechanism temperatures are still within their operational range, the ground will await the next overlapping NEN pass to deploy the Aquarius reflector boom. A pin-puller is initiated that releases the boom from the stowed configuration. Once released, the Lower Deployment Mechanism rotates and latches the boom to complete the second stage deployment. A limit switch provides the appropriate housekeeping telemetry that the reflector is stowed and a redundant pair of switches will indicate that the boom is latched in the deployed state. After reviewing Aquarius telemetry to ensure successful deployment, the S/P is taken out of Safe Hold to Mission Mode.

5.4.1.3.3 L+Day 27: Radiometer Turn-on

The third day of Aquarius commissioning is dedicated to turning on the Radiometer subsystem. The Aquarius Flight Operations Team (AFOT) will evaluate the Aquarius instrument telemetry to ensure that the radiometer temperatures are within operational limits prior to turning on the DPU. DPU telemetry from the high-rate science data will be evaluated prior to turning on the radiometer RF channels. The latter activity is initiated over overlapping NEN passes to allow for the maximum real-time monitoring and commanding possible. The radiometer should be able to retrieve brightness temperature, but not to the accuracy specified in the mission success criteria since the ATC is not on yet.

5.4.1.3.4 L+Day 28: Scatterometer Turn-on

The third day of Aquarius commissioning is dedicated to turning on the Scatterometer subsystem. The Scatterometer and its Processor/Control (SPC) board in the ICDS will be monitored and assessed prior to transmitting from the radar. The commissioning day culminates in the radar being commanded to transmit over overlapping NEN passes.

5.4.1.3.5 L+Day 29 to L+Day 31: Active Thermal Control Turn-on

The next three days of the Aquarius commissioning are dedicated to initiating the instrument’s ATC to complete the instrument’s turn-on activities. There are four temperature controlled zones on the Aquarius instrument that will be incrementally turned-on and checked out. AFOT requires high rate science packets before and after ATC is enabled to verify each micro-processor controlled zone is operating nominally. Zone 4 is the first region to be turned-on and checked out. Due to its larger thermal mass Zone 4 requires a longer time to stabilize. Temperatures in Zones 1-3 will stabilize in 2000 sec from turn-on. Considering the available number of high rate passes during the work-day and the stabilization durations, two and a half days are required to activate all four zones.

5.4.1.3.6 Day 32-45

Once all four zones are operational, the Aquarius Instrument checkout is complete. Aquarius is fully functional and operating in the Mission Mode and collecting science data for the remaining Early Orbit and Commissioning Phase. The remaining three days of the Aquarius Deployment and Commissioning Sub-Phase represents schedule margin in the event that additional time is required to complete a subsystem turn-on or checkout activity. However, if the three days are not needed, Aquarius will relinquish that time to the SAC-D instruments to begin their commissioning. During this time Aquarius will monitor the influence of the SAC-D instruments on Aquarius during their turn on.

5.4.1.4 Aquarius Commissioning Phase Success Criteria

At the end of the 45 day Observatory Commissioning Period, a Post Launch Assessment Review (PLAR) will be conducted to evaluate the instrument and mission system. The successful completion of the PLAR will be necessary prior to transition of Project Management. to the GSFC. The results of the instrument checkout and turn on procedures are collected for each commissioning activity and contribute important evaluation criteria at the PLAR. The following criteria for the Commissioning Phase assumes successful completion of the Launch Phase, including the L+0 day verification that survival heaters are enabled. The success criteria for each Commissioning activity are identified by day and activity below:

L+Day 25: ICDS

1. The S/P provides power to the Aquarius operational deployment heaters and sets up the automatic S/P fault protections of the Aquarius Instrument.
2. AFOT verifies that the ICDS & ADPU temperatures are within operational range.
3. S/P completes power-on of the SBE reference clock and ICDS in response to ground commands.
4. S/P enables autonomous fault protection after telemetry verification of successful ICDS boot up.
5. AFOT verifies that the ICDS and ADPU telemetry is nominal.
6. AFOT enables Aquarius ICDS autonomous deployment heater control.
7. AFOT monitors Aquarius deployment mechanism temperatures and adjust thresholds as necessary to the operating temperature ranges.

L+Day 26: Aquarius Deployments

1. AFOT monitors Aquarius deployment mechanism temperatures and adjust thresholds as necessary to the operating temperature ranges.
2. AFOT verifies that the ICDS limit switch telemetry is consistent with the stowed state and command sent to force S/P into Safe Hold Mode.

3. Commands sent to S/P to enable and fire both sep-nuts to release Aquarius reflector.
4. AFOT checks that limit switches indicate proper deployment of the Upper Deployment Mechanism.
5. AFOT verifies that the ICDS limit switch telemetry is consistent with the stowed state for the Lower Deployment Mechanism and the Lower Deployment Mechanism temperature within operating range.
6. Commands sent to S/P to enable and fire pin-puller to allow the Aquarius boom to deploy.
7. AFOT checks that limit switches indicate proper deployment of the Lower Deployment Mechanism.
8. Monitor reflector temperatures for several orbits prior to turning off operational deployment heaters.
9. Return S/P to nominal Mission Mode.

L+Day 27: Radiometer Turn-on

1. S/P Remote Terminal Unit (RTU) commanded to switch on power to Radiometer.
2. Monitor radiometer temperatures for several orbits prior to turning on DPU.
3. AFOT to verify DPU operating nominally via high rate science data.
4. The ICDS is commanded to power on the Radiometer Back End and Radiometer Front End, all channels.
5. Verify radiometer operational and collecting science data.

L+Day 28: Scatterometer Turn-on

1. Verify the scatterometer processor in the ICDS returns the appropriate "canned data" values without the scatterometer generating data
2. The S/P RTU is commanded to switch on power to the SSPA and the ICDS is commanded to turn on the rest of the Scatterometer.
3. Establish the scatterometer operational parameters including beam mode, beam width and position, and selection of chirp generator and step attenuator pair.
4. Command the Aquarius instrument into Receive-Only Mode after disabling the SPC ICDS "canned data" mode
5. AFOT disables Receive-Only Mode following confirmation of positive instrument health in order to activate radar transmission.
6. Monitor instrument health over several orbits.

L+Day 29 to 31: Active Thermal Control Turn-on

For every one of the four zones, the following products are collected:
1. S/P to turn on relay to power the ATC
2. AFOT initializes the ATC zone control parameters.
3. AFOT verifies the instrument health (from high rate data) and adjusts ATC micro-control parameter
4. Monitor ATC performance and instrument health from high rate data.

L+Day 32 to 45

Following Aquarius turn-on, the instrument will be monitored during the turn on of the SAC-D instruments to identify any observable thermal or RF signature or interference that may come from any of the SAC-D instruments. During this time Aquarius will be capturing the first science data set that could be used to generate salinity data products. These data will be compared to the power on strategy and timeline provided by CONAE.

5.4.2 MWR

5.4.2.1 Objectives of MWR Commissioning

The Objective of the MWR Instrument Commissioning is to transition MWR from the post-Launch configuration with the survival heaters enabled to the Mission Mode of Operations and verify that the instrument is ready to begin Science Operations.

The general activities associated with the MWR commissioning include power on and checkout and finally initial data collection.

This activity determines the health of the MWR instrument following the stress of launch and exposure to the space environment.

5.4.2.2 Ground Station Coverage

The NASA Ground Network (NEN), ASI Matera, and Cordoba (ETC) ground station will provide the necessary coverage to retrieve housekeeping telemetry following each commissioning step to verify successful command execution and readiness to proceed to the next step.

5.4.2.3 MWR Commissioning Schedule

MWR Instrument Commissioning starts 38 days after launch (see Figure 5-2) and assumes that the S/P has been fully checked out and PAD commissioning phase is successfully accomplished.

MWR has been allocated 3 days to complete the instrument checkout phase prior to beginning Initial Data Collection. Two days has been identified, with the remaining 1 day reserved as margin. If the third day is not needed, then the initial MWR data collection period begins 1 day early.

5.4.2.4 Mode Changes

MWR begins the Commissioning Phase in the Survival mode that started in the Launch fairing separation, 300 seconds after Launch approximately.

At the start of the MWR Commissioning phase, the instrument will be put into Standby mode by PAD for checkout and thermal stabilization within its AFT of Mission Mode.

Following, the rest of the instrument subsystems will be incrementally turned on until the Instrument mission mode is achieved (i.e., tight thermal control established, and instrument collecting science data).

5.4.2.5 MWR Commissioning Description

MWR Instrument commissioning begins with the power turn-on. Once the instrument power is turned on subsystems are incrementally checked for functionality. The turn-on sequence involves powering the Radiometer, and the activation of the Thermal Control subsystem via command. Roughly one day will be spent on checking out each of these subsystems.

5.4.2.5.1 L+Day 38: MWR Power on

The first day of the MWR instrument commissioning is dedicated to the power on process.

The S/P will provide telemetry to ensure that the receiver is within their operational range prior to its turn on.

The MWR instrument power on is a single command that turns all the subsystems of the instrument and let them on the stand-by mode of warm-up.

With the MWR Back-end operational, the instrument is able to receive ground and PAD commands and send to PAD the telemetry used for Thermal Control Subsystem.

After MWR is turned on, via a ground command, the Instrument will be set in Standby Mode and Thermal Control Subsystem will start operating receiving from PAD the correct PWM for each of the 12 heater cells. It’s anticipated that 5 (TBC) orbits are required to stabilize the instrument by the first time before it is able to pass to another operational mode.

5.4.2.5.2 L+Day 39: MWR change to Mission Mode

The MWR Team will evaluate the Instrument Telemetry to ensure that the radiometer temperatures are within operational limits prior to change to the another operational mode such as Diagnostic or Mission and turn on the RF or front-end sensitive components as the Noise Diodes.

Receiver’s telemetry from the high-rate science data will be evaluated prior to turning on the radiometer RF channels. The latter activity is initiated over overlapping NEN passes to allow for the maximum real-time monitoring and commanding possible. The radiometer should be able to retrieve brightness temperature.

5.4.2.5.3 L+Day 40-45

Once the whole MWR is on and correct functionality is checked in Mission Mode, the MWR Instrument checkout is complete. MWR is fully functional and operating in the Mission Mode and collecting science data for the remaining Early Orbit and Commissioning Phase.

The remaining day represents a schedule margin, but also a time when MWR may be checked simulating the contingency of the RX Protect signal broken-down, off or not synchronized.

However, if this day is not needed, MWR will relinquish that time to the following instruments to begin their commissioning. During this time MWR will continue monitoring the influence of the Aquarius and other SAC-D instruments on the MWR.

At the end of the 45 SAC-D Commissioning Phase, a Cold Sky Maneuver is required to the S/P in order to perform the first Cold Sky Calibration and start collecting calibrated science data.

5.4.2.6 MWR Commissioning Phase Success Criteria

The Commissioning Phase is considered successful if at the 45th day after launch the MWR is ready to send science date within its requirements.

5.4.3 NIRST

During NIRST commissioning phase, the pointing mirror retaining mechanism will be released and the mirror moved to 45º observing position.

The instrument performs its consistency checking as follows:

- Calibration will be performed by internal calibration subsystem and space observation, coincident with Aquarius Cold Sky Calibration.
- In situ measurements of will be used to validate NIRST data.

5.4.4 HSC

The SAC-D Ground System will process HSC data taken over moonless uniform dark ground features and known light sources and use this data to calibrate and validate data.

5.4.5 ROSA

ROSA commissioning activities verify the functionality and the preliminary performances of the Instrument. This activity is carried out during the Observatory commissioning phase (see Figure 5-2)

The objective is to declare the instrument ready for the start of nominal operations and fully usable by the customer (i.e. the scientific community)

The Commissioning is divided in two basic steps:

- Commissioning step A:
  - In flight Power-On of the Instrument
  - Evaluation of Power Consumption and Health Status Signal
  - Verification of Communication

- Commissioning Step B:
  - Functional tests on ROSA (Switch between Instrument Operative modes, Rx Start procedures)
  - Raw Data Analysis: Pseudorange, Carrier phase, SNR
  - Real Time Navigation verification
  - Observation Mode Tests

5.4.5.1 Commissioning step A

- ***Power On***: The Instrument is powered on in flight. In this initial step there is the need to verify that the instrument power supply is working nominally (without current limitation, power protection etc.) by direct analysis of the *satellite housekeeping data* (*nominal power consumption, temperatures etc*.). After powering, the instrument automatically starts the boot sequence.

- ***Verification of the communication- Health Status***: When the Instrument is correctly turned on there is the need to verify the communication link. When the flight ROSA SW program has been loaded the correctness of the data received (telemetry) shall be verified about different data packets type in format, content and periodicity. In this step the correct telecommand reception is also verified.

5.4.5.2 Commissioning Step B

The first three steps are standard part of the functional verification in flight of a space borne GPS receiver. TAS-I experience in this field is based on previous missions (SAC-C, ENEIDE).

Observation Mode Tests are limited to the basic occultation functionalities (i.e. geophysical parameters will not be retrieved in this phase). These tests require the availability of several inputs that shall be prepared in advance. In particular:

- High fidelity a-priori data (visibility and occultation predictions in time and location)
- Raw Data-processing routines
- Basic algorithmic processing functions to generate level 1 products

Observation Mode Tests can be summarized as follows:

- Check of ROSA occultation Satellite visibility against high-fidelity a-priori data.
- Number of occultation events/orbit
- Sounding point deepness in atmosphere
- L2 tracking capability in low atmosphere
- Open-loop data quality

The ROSA Instrument is highly configurable by a number of telecommands to tailor the in-flight occultation performances in case this is needed

6.0 Science Operations Phase

6.1 Nominal Mission Timeline

Following instrument commissioning and product validation, nominal science operations will start. In this phase the Observatory attitude will be set in the ***Yaw Steering*** mode by ground command.

Aquarius and SAC-D instruments will operate according to the following mission timeline:

- The Aquarius instrument will be operated continuously over the ocean and land. This schedule will provide the best thermal stability and simplicity of operation.
- The MWR instrument will be operated continuously
- The NIRST instrument will be operated on passages over Argentina, Italy, Canada and other opportunity targets around the world.
- The HSC instrument will provide imaging of Argentina, Italy and Antarctica.
- The DCS instrument will collect data from ground platforms taking environmental data over Argentina, Italy and Brazil
- The ROSA instrument will be operated continuously.
- The CARMEN instrument will be operated continuously.
- The TDP instrument will be operated continuously.

6.2 Service Platform

6.2.1 Attitude Emergency Modes

The default Service Platform emergency mode is Safe Hold mode which is similar to the nominal mission mode except that the LVLH is not implemented. In the worse-case scenario, the Service Platform would enter into Survival mode (otherwise known as B-dot mode) where the Observatory is rotating at 2 revolutions per orbit about the y-axis. The latter is a zero-momentum biased mode.

6.2.2 Orbit Maintenance

Drag Make-Up maneuvers (along track) to correct the orbit altitude will be performed every 28 days.

All inclination maneuvers should preferably be performed prior to Aquarius instrument commissioning to minimize potential loss of science data. However, depending of the Mean Local Time evolution, it might be necessary to perform a corrective inclination maneuver during the science operation phase.

6.3 Aquarius

6.3.1 Objective of Aquarius Science Operations

The Aquarius Mission will make global space-based measurements of sea surface salinity (SSS) with high precision, resolution, and coverage to investigate the coupling between ocean circulation and the global water cycle. The primary data product generated by Aquarius is monthly mean estimates of SSS over three years.

6.3.2 Aquarius Operations Needs and Constraints

6.3.2.1 Aquarius Science Orbit

The Aquarius/SAC-D science orbit is at 657±1.5 km altitude, 98 degree inclination, and a 6pm±5min ascending node. The orbit design provides Aquarius with four, 7-day global repeat tracks in a single 30.4 day month. The distance between consecutive orbit tracks measured at the equator is 2723 Km and the equatorial distance between consecutive ground tracks is 389 Km.

Inclination Adjustment Maneuvers, which require off-nadir attitudes are not planned during the Aquarius Mission. The only delta-V maneuvers planned, are the monthly Orbit Maintenance Maneuvers (OMM). Each OMM burn lasts a few minutes and the Observatory attitude will not change. Each OMM consists of two short burns separated by several orbits. In total, it will take 4 or 5 orbits to complete the maneuver but, since the attitude remains nadir Aquarius/SAC-D science data acquisition should not be interrupted by thermal transients.

Requirements for a longitude window maintenance of ±10 km and for OMM spacing of greater than 30 days can not both be met during periods of high solar flux. The +/-10 km longitudinal window can not be maintained with only one OMM per month between about Jan 2010 through June 2013. This can be made better or worse depending on the actual atmospheric drag which has an uncertainty of between +40% and -20%. SAC-D plans to adopt a longitude window that can be maintained with one maneuver per month.

6.3.2.2 Science Data Loss Budget

The science Data Loss Budget permits a cumulative loss of up to 2.4 days margin per month for instrument or S/P anomalies, and any activities that result in attitudes or thermal environments that contribute to loss or degradation of data.

The Aquarius science measurement is highly dependent on maintaining tight thermal control. Minimizing thermal transients has a direct relationship with minimizing science data loss. The Cold Sky Calibration will result in a thermal transient, which is expected to degrade data products for about one orbit.

Out-of-plane maneuvers are not planned during the Aquarius Mission, however if they are needed, Aquarius may be temporarily placed in Standby Mode or OFF with survival heaters to conserve power. This will result in lost or unuseable instrument data during the time off and during the time it will take to re-establish instrument thermal stability. This could degrade data for several orbits.

6.3.2.3 Operations Ground Station Network

ETC is the primary ground station for the Aquarius/SAC-D mission. In addition to ETC, the ASI Matera ground station will augment the X-band station coverage to nominally preclude station gaps of greater than 6 hours. This second station minimizes the potential loss of data due to ETC station outages, inclement weather or data downlink errors. On average, there are four passes per day planned over ETC (twice each morning and twice each evening). The Level 2B Requirements for Aquarius downlink every 6 hours or less implies that at least two passes per day need to be planned over Matera (once each morning and once each evening).

SAC-D uses a 4 kbps S-band link for commanding and also for real time downlink of low rate (8 second) HKT. SAC-D uses a 16 Mbps X-band downlink exclusively for high rate downlink of data including science data, stored high rate HKT (1.44 second), and stored low rate HKT that was generated between S-band contacts and not sent in real time. Real time telemetry only comes down S-band. Downlink over Malini or Matera must be initiated with time-tagged commands since these stations do not have an uplink capability. High rate downlink is not possible over the S-band only NEN and Malindi stations.

Ground Station	Frequency Band	Link Capability
ETC	S-band X-band	uplink/downlink downlink
NEN	S-band	uplink/downlink
Matera	X-band	downlink
Malindi	S-band	downlink

Table 6-1 Ground Station Capabilities

Often, activities such as the Cold Sky Calibration, will desire telemetry or data products before an ETC opportunity is available to verify the safety of the Observatory or facilitate efficient operations. In these cases, or in the event of anomalies, the ASI Malindi, and the NASA Ground Network stations are available for additional coverage. Use of the ASI Matera station could also be expanded.

In emergencies, the mission will utilize the NEN ground stations to receive real time HKT and to transmit commands. The Malindi station may be available for receiving real time HKT but it has no uplink capability for SAC-D.

6.3.3 Aquarius Data Handling

6.3.3.1 Command Development Cycle

Once per week, the SAC-D Ground System provides the AFOT with the upcoming two-week pass-plan schedule. Aquarius then develops two week long pass plans with the timing of all downlink durations and settings and sends that to CONAE for incorporation into the Observatory sequence. The uplinked commands are frozen, one week before uplink. They are uploaded to the Observatory the following week. The figure below summarizes the pass plan development cycle.

When commands are uploaded by the MOC, a Pass Plan Execution Report is generated and provided to the Aquarius Command and Control System.

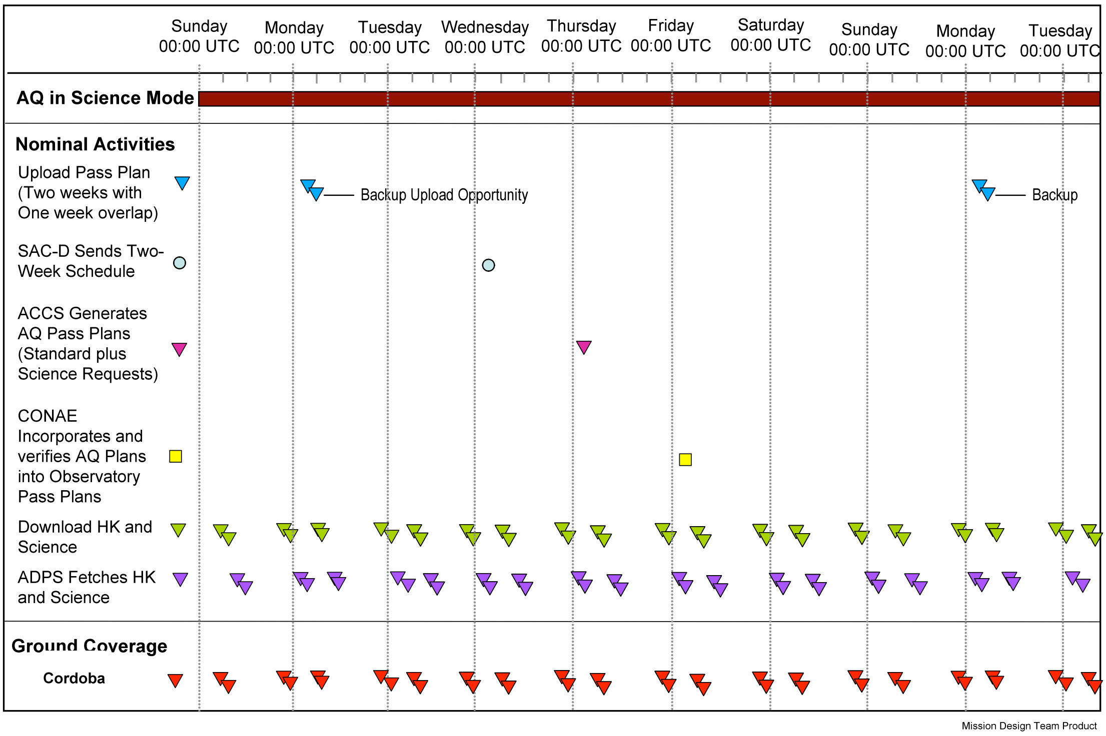


Figure 6-1 Aquarius Week in the Life

6.3.3.2 Aquarius Commanding Interfaces

Aquarius is only capable of handling real-time commands. However, Aquarius receives all ground commands via the S/P. The S/P can handle either real time or time-tagged ground commands. This feature allows Aquarius commands to be time-tagged, stored on the S/P until their scheduled execution times, and then released to Aquarius where they perform as real-time commands. The pass plans are examples of time-tagged Aquarius commands that are run by SAC-D C&DH. The S/P issues these time-tagged commands to Aquarius as real-time commands.

Aquarius fault protection is handled through the S/P autonomous fault protection. Aquarius anomaly recovery is handled exclusively by ground command.

6.3.3.3 Aquarius Onboard Data Handling

Aquarius commanding and data handling is controlled by the ICDS, which receives all commands routed through the S/P C&DH. Aquarius does not have a solid state recorder and uses the Rad6000 DRAM (volatile memory) to store science data. 110 MB of the total 128 MB of RAD6000 DRAM is allocated for storing the Aquarius science packets, which include both Science data and the high rate HKT data. The remaining 18 MB are reserved for running the FSW and storing FSW patches. The 110MB storage allocation represents enough space for approximately 15.8 hours of Aquarius science data. If there is a Power On Reset of the instrument, then the stored science and housekeeping data and FSW patches are lost.

The S/P C&DH requests a 500 byte low rate HKT packet from Aquarius every 8 seconds. If the S/P S-band transmitter is active at that time, the Aquarius HKTs are packaged with the other 3500 bytes of the Observatory HKT frame and are transmitted to the ground in real time. Otherwise, the 4000 byte AQ/SACD HKT frames are stored in the S/P Mass Memory.

During Cordoba and Matera passes, the stored HKT frames are transmitted to the ground via the 16 Mbps X-band channel along with all other SAC-D Mass Memory data.

The high-rate Aquarius science packets stored on the ICDS DRAM are downloaded after receipt of the start-downlink command from the SAC-D C&DH. Data is read out sequentially beginning with the position of the read pointer. When the end of the buffer is reached, the download readout continues at the start of the buffer. This process continues indefinitely until the stop-download command is received.

Data read out from the Aquarius DRAM buffer is routed through the S/P Mass Memory as the S/P C&DH formats it into CCSDS packets and forwards it on to the X-band transmitter.

6.3.3.4 Aquarius Data Downlink

Aquarius plans to continue to collect and store instrument data in the nominal Mission mode throughout the entire downlink event over every ground station. Aquarius plans to downlink stored data over every ETC pass greater than 2.9 minutes long, and over scheduled Matera passes. Aquarius plans to download data, often redundantly, for the entire duration of every station pass. The Aquarius pass plan starts the downlink of high rate science data after the scheduled SAC-D X-band transmitter turn-on command and stops the downlink just prior to the scheduled SAC-D X-band transmitter turn-off command.

The Observatory allocates Aquarius a dedicated 4 Mbps virtual channel from the 16 Mbps X-band link to download the stored data during each ETC and Matera pass. The ground station passes vary from 3 to 11 minutes. On average, Aquarius will be able to downlink at least three redundant copies of the 110MB of science data before it is overwritten.

In order to be able to accommodate a single missed downlink pass without loss of redundant data downlink, the ICDS will always downlink starting with the data collected from the pass before the previous downlink. This covers the worst case scenario of ensuring that gaps of up to 13.2 hours (92 MB of collected data) are able to come down over even the shortest ground pass of 3 minutes. This strategy, in addition to continuous playback of science data throughout the entire pass, results in a significant redundancy in science data downlink with 3 or more redundant copies of the science data blocks.

6.3.3.5 Ground Data Handling

The real-time HKT data is downloaded from the Observatory to the SAC-D MOC and monitored to verify the Observatory health and status. For Observatory passes over other ground stations, real-time HKT data will be transferred from the NEN or ASI station to the SAC-D MOC.

The stored Aquarius science data and ancillary data are routed from the ground station to the SAC-D MOC. Once receiving the data, the MOC then provides the data to the Aquarius Ground system, where it is processed into the monthly SSS maps and other science data products

6.3.3.6 Flight Software Changes

The FSW architecture has three levels of command handling and data processing: The Service Platform C&DH, The Aquarius ICDS, and the Radiometer DPU. The Service Platform C&DH routes all commands and data between Aquarius and the ground. The ICDS is the Aquarius instrument command and data handler. It contains the Aquarius flight software and provides the interfaces between the Service Platform C&DH and the Radiometer Digital Processing Unit (DPU). The DPU performs the command and data handling for the Radiometer.

The ICDS flight software and the DPU firmware will be fully tested prior to launch. However, it is possible that in-flight characterization of performance will motivate the need to make software updates to the ICDS or Lookup Table changes to the DPU. JPL has provided a Flight Software User’s Manual that addresses ICDS software changes. The Goddard Radiometer team has provided a Radiometer Handbook that addresses changes to Lookup Tables. Aquarius Standard Operating Procedures include procedures for each of these activities, although the specific script for any change will have to be created and tested separately.

Mission Operations will monitor instrument performance and the Science team will monitor science performance. If either team determines that software or Lookup Table adjustments might be appropriate, Science and Mission Operations will work together with temporary support from the JPL Flight Software Team or the Goddard Radiometer team to devise the updates, formulate a script, and to test that script against the Aquarius test-bed. The final script will also be tested by CONAE against the Observatory test-bed prior to upload to the Observatory. Final upload authority will require concurrence of Aquarius PI (or designee), Aquarius Ground System Management, and CONAE Ground System Management.

Although real-time uploads to either the ICDS or the DPU are possible, the Standard Operations Procedures call for uploading software scripts as a series of time-tagged commands that are loaded into the S/P C&DH. The commands that load the patch or Lookup Table change are sent to the ICDS (or via the ICDS to the DPU) according to their time-tags and are immediately executed by Aquarius. These commands are typically executed between ground station passes. The final implementation of the new patch or the new Lookup Table is executed as a real-time command after the Aquarius and SAC-D Flight Operations teams have both verified that the script executed as expected.

For both the ICDS and the DPU the flight software loads into RAM from EEPROM. Any changes to software are applied to the copy in RAM. Thus, a reset of the ICDS (which would also reset the DPU) would require a complete reload of all prior patches and tables. A reset of the DPU only would require a reload of Lookup Table changes. Prior to these reloads, the units would revert to the original software stored in EEPROM.

6.4 MWR

6.4.1 Nominal Mission Timeline

Following instrument commissioning and product validation, nominal science operations will start. MWR will operate according to the following mission timeline:

- The MWR instrument will be operated continuously
- The MWR instrument will be operative over 3 years
- The MWR instruments will perform cold sky calibration coincidently with Aquarius.
- During MWR data processing, data retrieval over stable thermal earth targets will be used to calibrate instrument performance and validate science data.
- In situ data will be obtained from the Servicio Meteorológico Nacional, INTA stations and the Data Collection System to validate MWR data.
- In situ measurements of geophysical parameters will be used to validate MWR data.

6.4.2 MWR Data Handling

6.4.2.1 Command Development Cycle

Once per week, the SAC-D Ground System provides the upcoming two-week pass-plan schedule. MWR Instrument then develops two week long pass plans with the timing of all downlink durations and settings and sends that to CONAE for incorporation into the Observatory sequence.

When commands are uploaded by the MOC, a Pass Plan Execution Report is generated and provided to the MWR Engineering Group.

6.4.2.2 MWR Commanding Interfaces

MWR is only capable of handling real-time commands. However, MWR receives all ground commands via PAD. PAD can handle either real time or time-tagged ground commands. This feature allows MWR commands to be time-tagged, stored on the S/P until their scheduled execution times, and then released to MWR where they perform as real-time commands.

6.4.2.3 Onboard Data Handling

MWR commanding and data handling is controlled by PAD, which receives all commands routed through the S/P C&DH. A total of 128 MB of the PAD mass memory is allocated for storing the MWR science packets, which include both Science data and the high rate HKT data. This memory allocation permits two complete days of science and HK data storage without downloading, being flexible to a S/P problem

6.5 Cold Sky Calibration

6.5.1 Objective of the Cold Sky Calibration

The Aquarius and MWR instruments are expected to have some degree of non-random internal noise bias to its measurements. The Cold Sky Calibration (CSC) activity is necessary to perform regular absolute calibration observations of thermally stable, cold regions of space to remove this bias in the Aquarius radiometer and antenna from the data sets. Monitoring the trends of these calibrations establishes the stability of the Aquarius internal noise, which in turn determines the frequency of the activity.

The CONAE Microwave Radiometer monthly calibrations will usually be coincident with the Aquarius CSCs during the operational life of the Aquarius instrument.

6.5.2 Cold Sky Calibration Plans, Constraints, and Development Guidelines

6.5.2.1 Cold Sky Calibration Frequency

The first CSC is planned to follow after the first 28 day salinity map is completed, approximately 2.5 months after Launch. Subsequent CSCs will be nominally planned once per month, although they may be scheduled more (or less) frequently as required. The CSC location and timing will be governed by the sky location of the galactic plane, which varies over the seasons, and considerations for partition of ocean, ice and land brightness temperatures in the antenna back lobes during the calibration. Aquarius and MWR plans to schedule the CSCs to minimize interruptions to the weekly global maps.

The required frequency of the Aquarius CSC will be assessed based on performance indicators of the instrument, NEN coverage and scheduling, impacts on data loss, instrument thermal stability, and other Observatory activities including SAC-D instrument operations.

Coupling the CSC with the monthly Orbit Maintenance Maneuvers is an option that can be evaluated on a case by case basis to improve operations efficiency and minimize gaps in AQ science due to thermal disturbances. There is no requirement that drives combining these two activities.

6.5.2.2 Cold Sky Calibration Configuration Changes

This activity happens out of ground station contact so the CSC maneuvers must be performed via stored commands in the S/P Command and Data Handling (CDH) subsystem. To minimize the thermal impacts of the CSC, the Observatory maintains the standard Mission Mode with the exception that the SAC-D High Sensitivity Camera (HSC) payload is placed in stand-by and the Data Collection System (DCS) payload is placed in OFF.

The Observatory slew will maneuver the system to the desired target region and <no inertial pointing provided by the Observatory attitude control subsystem allow the Aquarius instrument to view a thermally stable region of space for about 1 minute. Following the CSC data collection, the Observatory will be commanded by stored commands to reverse the slew and return back to the normal mission attitude.

Throughout the CSC the Aquarius instrument will maintain its nominal mission mode collecting and storing the data that will be used to calibrate the instrument. Specifically, Aquarius measurements will be made throughout the maneuver, while pointed at the target area, and during the reverse slew back to nadir. After the CSC calibration, the observatory attitude will be at nadir point, in Mission Mode and with nominal operations restored including returning power to the DCS and re-enabling the HSC.

6.5.2.3 Cold Sky Calibration Targeting and Slew Constraints

The Aquarius ground system will develop procedures to determine and request; the target region, timing constraints, and ground station coverage. The procedures for defining and delivering these parameters to CONAE are still in work but are expected to be similar to procedures established for Seawifs.

The target used for the CSC must be thermally stable to determine the non-random noise in the radiometer, and it must be performed over a stable temperature region of the Earth, like the oceans, in order to determine the contribution of the antenna backlobes. Additionally, the sun needs to be more than 90° and the moon more than

15° from the main beams. Based on the Sun-synchronous orbit with ascending node at 06:00 PM, these are easy constraints to meet and operations procedures for determining the timing will include a verification of this.

The targeted region must be large enough in extent that the Observatory can maintain an attitude pointing within it for a period of about 1 minute. In the case of Aquarius, and the assumed slew rates, these criteria last several 10's of seconds and the source (cold part of the sky) is fairly large so there is flexibility on the slew rate and pointing needs.

The slew profile must be designed such that the nadir deck does not point in the orbit velocity direction.

The slew profile must also minimize thermal transients to the Observatory. Thermal transients are unavoidable due to the time required to perform the CSC maneuver and the location of Earth with respect to faces of the Observatory that usually see only cold space. The thermal transients will be most significant on the radiometer antenna since its thermal state is not controlled. The minimum Flight Allowable Temperature on the antenna is -132C. Worst case thermal analyses predict a minimum temperature of -119C for a 40 minute activity consisting of a 180 degree turn from nadir to zenith (initiated at eclipse exit in the 58.5 degree beta angle orbit), a 10 minute dwell, and a 180 degree return from zenith to nadir.

6.5.3 Cold Sky Calibration Activity Description

6.5.3.1 Cold Sky Calibration Maneuver Description

Aquarius needs the S/P to change the Observatory attitude such that the Aquarius instrument will view a cold, thermally stable area for 1 minute with a thermally uniform nadir surface to prevent unwanted noise being observed in the instrument's antenna side lobes. The actual constraints on dwell duration will be evaluated on a case-by-case basis.

The baseline plan for the CSC maneuver is to pitch the Observatory away from the velocity vector with a positive pitch. This technique will take advantage of the Observatory's lowest moment of inertia and prevent the nadir deck instruments from being pointed in the direction of the velocity and minimizes their exposure t atomic oxygen and space debris. During Science Operations, the S/P maintains nadir tracking with a positive, relatively constant pitch rotation about the Observatory –Y body axis. For the CSC maneuver, increasing the magnitude of this pitch rate will result in a slew of the nadir deck toward zenith through the anti-velocity vector. At the target area attitude, the Observatory –X body vector is aligned with the velocity vector. This attitude will maintain similar power and thermal states as experienced from the normal Mission Mode attitude since the Sun is still more or less still aligned in the Observatory –Y direction.

The baseline pitch back to nadir will be in the opposite (negative pitch) direction, again avoiding exposure of the nadir deck in the velocity direction. An additional benefit of reversing the slew direction is that it unloads the momentum built up during the slew out.

Figure 7 shows the view from behind the Aquarius sun shade in the direction of the Observatory –Y body axis in the general direction of the Sun with respect to the velocity vector, and nadir to Earth. The three attitudes shown are 1) the normal nadir pointed attitude showing the CSC pitch direction, 2) The CSC attitude with –Z nadir to Earth and –X aligned with the velocity vector, and 3) the pitch direction used to return to the normal nadir pointing.

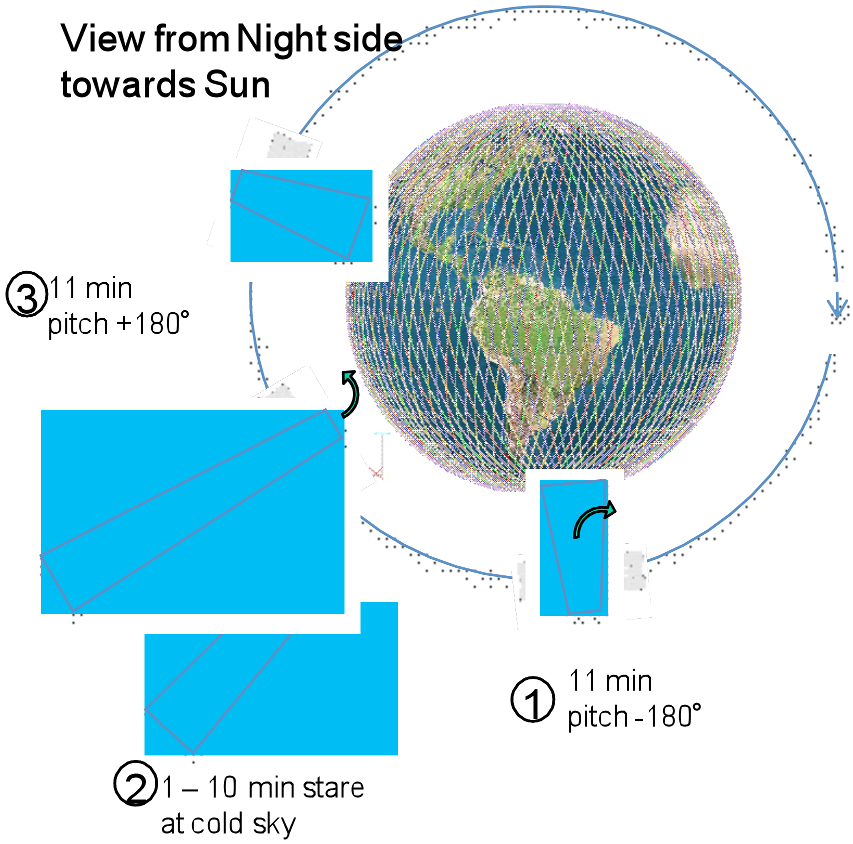


Figure 6-2 Cold Sky Calibration Maneuver

The observatory +Y body axis points out of the page in all three diagrams and it can be seen from this that the sun maintains a similar orientation with respect to the Observatory as seen normally in orbit. The maneuver design compliments the existing S/P capability of slewing at 0.3 °/second. This performance decreases to 0.2 °/second with the failure of one reaction wheel.

6.5.3.2 Cold Sky Calibration Ground Station Plan

CSCs will be implemented through stored commands integrated in pass plans uplinked over the Cordoba ground station, ETC, since the constraints on the maneuver target area and background will not allow the maneuvers to be performed over any of the supporting ground stations.

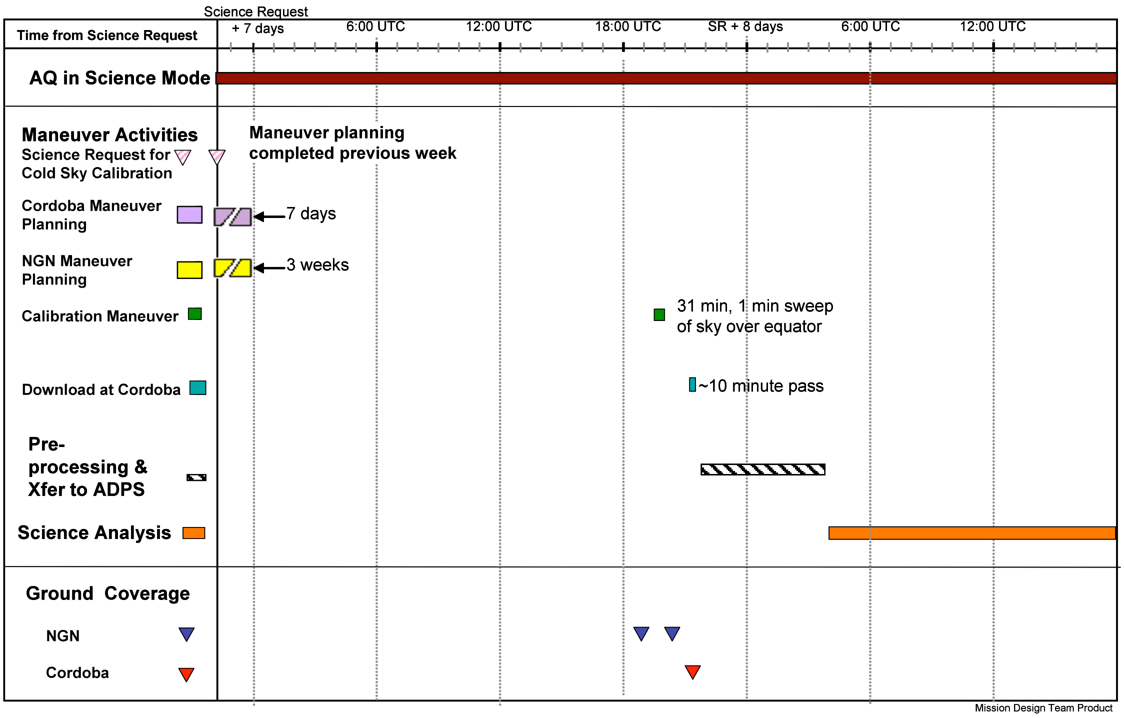
NEN station passes will typically be scheduled immediately before and immediately following the CSC to monitor the real time HKT more closely, and provide contingency command capability before and after the CSC. Regularly scheduled ETC passes may be as much as 10 hours apart and the ASI Matera and Malindi stations do not have S-band capability so they can neither relay real time HKT nor can they provide uplink capability. Downlink of the calibration data is planned over the next Cordoba pass opportunity, after which the data is preprocessed and placed on ADPS for analysis.

6.5.3.3 Cold Sky Calibration Sequence Development

In order to plan the timing and targets for the CSC maneuvers, NEN requires at least 3 weeks advance notice to schedule such an activity and the CONAE ground system requires at least 7 days advance notice for operational planning of a Cold Sky Maneuver. Commands sequences are frozen 7 days before uplink.

The target region and calibration opportunity timing for the CSC will be identified by the AFOT. Once the request has been made as to when and where the maneuver is to take place, the time tagged commands are built by CONAE and transmitted to the Observatory to execute autonomously.

Figure 6-3 shows an overall timeline of the CSC activity including the development timing associated with building the command products. The Figure shows representative timing of the associated development tasks needed to generate the CSC sequence. The activity is shown with a green bar towards the center of the timeline indicating the 31 minutes allocated for the slew to the target, making the needed observations, and the slew back to nadir. NEN passes are shown both before and after the sequence is performed.



1.- Minimum time between CSC data collection over the equator and ETC pass is 7min. (descending pass over Atlantic) which means observatory still implementing a -180° maneuver
2.- Maximum time between CSC data collection over the equator and ETC pass is 622.5 min (descending pass over pacific)

Figure 6-3 Cold Sky Calibration Timeline

7.0 Observatory Decommissioning Phase

At the conclusion of the Science Operations Phase, the Observatory will perform a de-orbit maneuver and then the Aquarius/SAC-D instruments and S/P subsystems (except C&DH subsystem receivers) will be powered off in preparation for uncontrolled re-entry.

To comply with the current space debris mitigation policy, the decommissioning phase will conclude with a series of de-orbit maneuvers. These maneuvers will reduce the perigee altitude of the Observatory to force it to re-enter the atmosphere and burn up in less than 25 years. During this time, the spacecraft is placed in a spin mode and commanded to take the anti sun direction causing the batteries to discharge.

If there is insufficient propellant available to perform these maneuvers, the Observatory will be placed in a high-drag orientation to hasten the re-entry.

8.0 Appendix A: Aquarius Instrument Modes

8.1 Summary of Aquarius Modes of Operations

Aquarius has four modes of operation: Mission Mode, Standby, OFF with Survival relays, and OFF without survival relays. The Aquarius instrument operational modes are largely independent of the S/P modes, however, if the S/P requires load shedding, Aquarius may be placed into either Standby, or OFF with Survival power enabled. Below is a more detailed definition of the Aquarius Instrument Modes and associated sub-modes:

8.1.1 Mission Mode

Mission Mode is the normal operating mode used during the Mission. Mission Mode is characterized by the Aquarius instrument in the final, deployed flight configuration, collecting scatterometer and radiometer science data and maintaining tight thermal control. This is the desired Aquarius operational mode for all Observatory modes including orbit maintenance maneuver and Cold Sky Calibration as it enables active control to meet Aquarius' thermal stability needs. Aquarius requires 375W orbital average in this operational mode.

8.1.2 Standby Mode

Standby Mode is the Power On Reset mode for Aquarius. While in Standby Mode, only the Instrument Command and Data Subsystem (ICDS), Scatterometer Back End (for ICDS reference clock), and portions of the Aquarius Power Distribution Unit (ADPU) are powered on. In addition to Power on Resets, the instrument will be in this mode before and during the reflector and boom deployment. The Aquarius instrument draws approximately 300W (orbital average) in this mode.

8.1.3 OFF with Survival Mode

In this Mode, the Observatory provides power to the Aquarius instrument for instrument survival. Aquarius survival heaters need 250W on average (580W peak) to ensure instrument safety when non-operational. During the first 25 days after launch, Aquarius will exist in this mode. In the Science Operations Phase, this mode would only be implemented if there was an Aquarius instrument anomaly, Observatory anomaly, or if necessary during an inclination maneuver.

8.1.4 OFF without Survival Mode

The entire Observatory is OFF during the first five minutes following launch. Only when the fairing is jettisoned, will the S/P power on, enabling instrument survival power. In the Science Operations Phase, Aquarius has identified a prioritized turn-off sequence for the Aquarius survival loads in the *Aquarius Instrument Interface Control Document (ICD) with the SAC-D S/P*. Powering off the Aquarius survival loads can lead to permanent instrument damage. This mode is never planned to be used again due to the potential for risk to the instrument health.

8.1.5 Diagnostic Sub Modes

If there is an in-flight anomaly with the Aquarius Instrument, there are a number of diagnostic sub-modes between Standby and Mission Modes the Aquarius Operations team can implement. These are driven by the subsystem states which include, but are not limited to:

Scatterometer Sub-Modes:

1. Scat is OFF: radiometer thermal control is close to nominal.
2. Single beam mode – scatterometer using only one of three beams, selected by command, to collect H & V polarization data. The data processing and timing is unchanged, but the science data block is filled with data from the selected beam.
3. Scat canned data mode: data processor canned data is used instead of science ADC inputs. This mode is used during Aquarius instrument turn-on sequence.
4. Test load mode: scat H/V/load switch is parked in internal load position with receiver switching related to the loopback calibration path. No scatterometer science data collected since not looking at the earth, although data processing is unchanged. This mode is part of the turn-on sequence but primarily used for debugging. There are thermal constraints associated with transmitting into the internal test load.
5. Scat is in safe state. All scatterometer switches statically parked (all inputs are into internal loads). Data processing is unchanged.
6. Receive Only mode: scatterometer not transmitting but receiving L-band signal from the earth. No scatterometer science data collected. No RF signal sent to the SSPA, which may be powered OFF. This mode is an intermediate step in the Aquarius turn-on sequence. This mode allows the ground to verify the scatterometer operational health prior to pulsing the radar. This mode could also be used to debug the radiometer by eliminating the scatterometer transmit as a possible source of interference.

Radiometer Sub-Modes

1. One of the radiometer beams, defined as one set of H, V, and ± 45°, is OFF. Thermal control of the radiometer is maintained close to nominal. This mode would be used in the event of failure of one of the 3 radiometer beams, or as a diagnostic. This mode would impact science since there would be permanent gaps in the ground swath footprint. Data format and downlink is unchanged.
2. Two radiometer channels are OFF. Thermal stability is not within specification since there is not enough replacement heat. There would be significant gaps in the ground swath. Data format and downlink is unchanged.

3. Radiometer is in safe state. All inputs are switched into loads. Data format and downlink is unchanged.
4. Radiometer is in a non-nominal sequence or a custom uplinked sequence (i.e., change the Look Up Table that defines the radiometer operational sequence). This mode can be used for science purposes, for diagnostics or as a response to some failure/anomaly.

ATC Sub-Modes

1. ATC is OFF in any of the thermal control zones. Can be used for trouble shooting or in case of a failure.
2. ATC is in constant power mode (instead of constant set-point temperature). This mode can be used for trouble shooting or as a back-up reduced performance mode in case of some failure mode. During turn-on, this mode is implemented prior to enabling ATC software.

8.2 Verifying and Commanding Aquarius Modes

Aquarius instrument telemetry will unambiguously specify the instrument subsystem states and consequently the operational or diagnostic mode.

Aquarius plans on operating in the Mission Mode during the majority of the mission. The S/P provides the autonomous fault protection for the instrument, primarily load shedding in case of over-current or over temperature, and a Reset in case of 1553 Watch-Dog failure. There is no instrument autonomous fault protection that would transition Aquarius out of Mission Mode.

Aquarius can change modes through ground command. Aquarius can not be commanded directly from OFF to Mission Mode without first changing to Standby. From Standby to Mission mode there are a number of potential diagnostic modes that the instrument can operate in as described above.

9.0 Appendix B: Acronyms, Abbreviations and Symbols

AOCS	Attitude and Orbit Control Subsystem
CGS	CONAE Ground Segment
CSC	Cold Sky Calibration maneuver
EOL	End Of Life
LVLH	Local Vertical Local Horizon Reference System
L/V	Launch Vehicle
PAD	Data Acquisition and Processing subsystem
S/P	Service Platform
SSS	Sea Surface Salinity

Table 9-1 List of acronyms, abbreviations and symbols